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ELEMENTARY DISCUSSION OF STRENGTH OF BEAMS UNDER TRANSVERSE LOADS.

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II.

Case IV.

Let the load be equally distributed over the beam (Fig. 32). In this case the reaction of each abutment $=\frac{1}{2}$ the load, or

$$R_1=\frac{wl}{2}=R_2 \qquad (36)$$

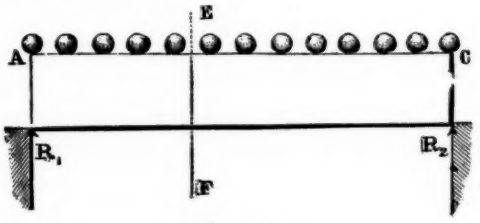

Fig. 32.

Take any section E F whose distance from A $=x$. Then the external forces acting between A and E F are, R_1 and the resultant of all the little weights from A to E $(=wx)$. This last force acts at its centre of gravity (Fig. 33),

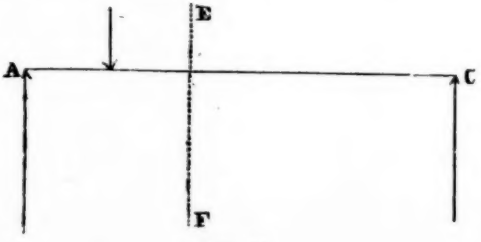

Fig. 33.

which is half way from A to E. Its lever arm is therefore $=\frac{x}{2}$. Hence the equation of moments will be

$$\left.\begin{aligned} \frac{wl}{2}\cdot x-\frac{wx^2}{2}&=\frac{1}{6}\,S\,b\,d^2=M \\ \text{or}\quad \frac{wx}{2}\,(l-x)\ &=\frac{1}{6}\,S\,b\,d^2=M \end{aligned}\right\} \quad (37)$$

This is a maximum at the centre where

$$M_0=\tfrac{1}{8}\,wl^2 \quad (38)$$

The shearing force at E F is

$$T=\frac{wl}{2}-wx \quad (39)$$

This is greatest at the abutments where $x=l$, or 0

$$\therefore\ T_0=\frac{wl}{2} \quad (40)$$

At the centre $T=0$

Geometrically. The values of M in eq. (37) may be represented by a parabola with vertex at L, the ordinates G L (Fig. 34) being taken $=M_0$. The shearing force is represented by the two triangles A P G and G Q C (Fig. 35).

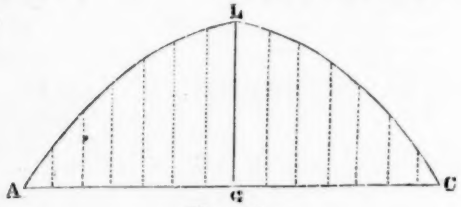

FIG. 34.

FIG. 35.

The maximum moment exists at the point (G) when the shearing force is zero.

Corollary. When the uniform load extends only over a certain distance from one of the supports, as in (Fig. 36),

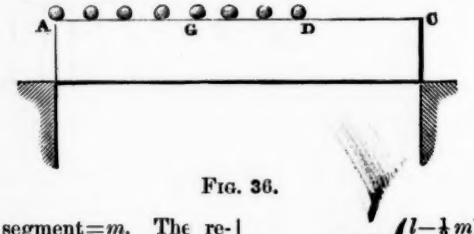

FIG. 36.

let A D=loaded segment=m. The reactions of the abutments are:

$$\left.\begin{aligned} \text{At A, } R_1&=wm\left(\frac{l-\frac{1}{2}m}{l}\right) \\ \text{At C, } R_2&=wm\left(\frac{m}{2l}\right) \end{aligned}\right\} \quad (41)$$

Then for any section in A D the moments of the external forces will be as in the case just discussed,

$$=wm\left(\frac{l-\frac{1}{2}m}{l}\right)x-\frac{wx^2}{2}$$

And the equation of moments in A D will be:

$$wm\left(\frac{l-\frac{1}{2}m}{l}\right)x-\frac{wx^2}{2}=\frac{1}{6}\,S\,b\,d^2=M \quad (42)$$

For any section in D C the whole load (wm) is to be considered as acting

through its centre of gravity (G), and the equation of moments is:

$$wm\left(\frac{l-\frac{1}{2}m}{l}\right)x-wm(x-\tfrac{1}{2}m)=\frac{1}{6}\,S\,b\,d^2=M$$

Reducing

$$\frac{w\,m^2}{2\,l}\,(l-x)=\frac{1}{6}\,S\,b\,d^2=M \qquad (43)$$

The shearing force in A D is

$$T=w\,m.\left(\frac{l-\frac{1}{2}m}{l}\right)-w\,x$$

In D C, $$T=w\,m.\left(\frac{l-\frac{1}{2}m}{l}\right)-wm \qquad (44)$$

T is a maximum at A, or

$$T_0=w\,m\left(\frac{l-\frac{1}{2}m}{l}\right)$$

Geometrically. Eq. (42) corresponds to the parabola A L K (Fig. 37), which

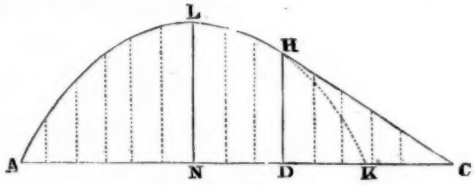

Fig. 37.

cuts A C at A and K (whose distance from A $=\frac{2\,m}{l}\,(l-\frac{1}{2}\,m)$) and whose axis is vertical. Eq. (43) corresponds to the straight line H C. We only use the part A L H of the parabola, the moments in D C being represented by the triangle D H C. The maximum moment is at N corresponding to the vertex L of the parabola. The value of this moment is:

$$M_0=\frac{w\,m^2}{2}\left(\frac{l-\frac{1}{2}\,m}{l}\right)^2 \qquad (45)$$

which is obtained from eq. (42) by substituting for x the value A N $(=\frac{1}{2}$ A K$)=\frac{m}{l}(l-\frac{1}{2}\,m)$. This M_0 is always less than the maximum moment that exists when the load extends all over the beam as will appear by making m to vary in eq. (45) and applying the tests for a maximum to it.

The shearing stress for the loaded segment is represented by the triangles A P K and K P′ D (Fig. 38), and for the

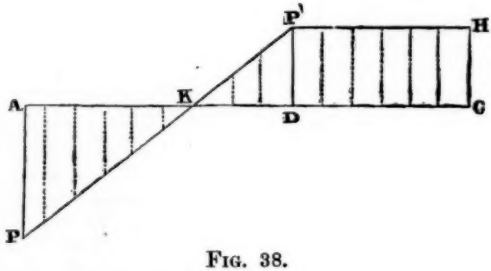

Fig. 38.

other segment by the rectangle D H. The point K, where the stress is zero, is found by making in eq. (44)

$$T=w\,m\left(\frac{l-\frac{1}{2}\,m}{l}\right)-w\,x=0$$

and finding the value of x.

This point corresponds to the maximum moment. It may also be found graphically by constructing Fig. 38, and, as before, affords the easiest method of determining the point of the beam where the maximum moment exists and where consequently there is greatest danger of rupture.

EXAMPLES.

1. Let l=20 ft. w=500 lbs. per ft. m=15 ft. and let there be a weight in

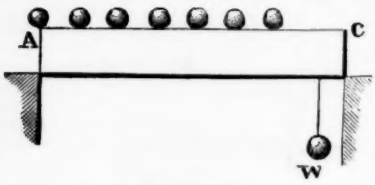

Fig. 39.

addition. W=5 tons at a point 18 ft. distant from A. Required the maximum moment.

2. Let one-half of the above beam be loaded with a uniform load, w=1 ton

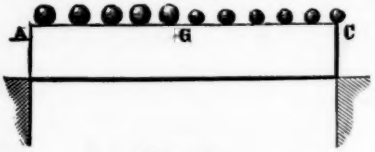

Fig. 40.

per foot, and the other half with a uniform load of $w'=\frac{1}{2}$ ton per foot. Required the moments.

Case V.

A single moving load. When a single moving load passes over a beam, as in (Fig. 41), the maximum moment at each

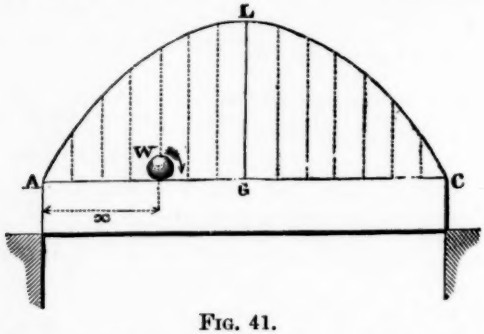

Fig. 41.

instant (as appears from *Case III.*) takes effect at the section just under the weight. To determine the law of variation of these maxima as the weight travels over the beam: Let x=the distance at any instant from A, and then the reaction of A at that instant (=the part of W transmitted to it)=$W\frac{l-x}{l}$ Multiplying this by the lever arm x we have for the moment under the weight:

$$\frac{W\,x}{l}(l-x)=\frac{1}{6}S\,b\,d^2=M \qquad (46)$$

This is a maximum at the centre, where

$$M_0=\tfrac{1}{4}\,W\,l \qquad (47)$$

Eq. (46) corresponds to a parabola (Fig. 41) with vertex at L, the ordinate G L being=$\frac{1}{4}$ W l. The shearing force for each segment into which W (Fig. 42) at any instant divides the beam is equal to the reaction of the abutment corresponding to that segment. Thus, if W is at a distance x from A the reaction of A is=$W\frac{l-x}{l}$ and of C it is=$W\frac{x}{l}$.

If W has the position marked 2 in (Fig. 42), then the shearing stress in the left segment is shown by the rectangle A N N′ W and in the right segment by the rectangle W N″ N‴ C. The diagram shows in a similar way the stress at other points. If the third position of W in the figure is at the centre of the beam then evidently the greatest shearing stress to be provided for in the left half of the beam will be represented by the *locus* of the points like L, N′, P′, and for the right half it will be the *locus* of the points P″, Q″, L′, etc.

These *loci* are given by the equations:

$$\left.\begin{aligned} T&=\frac{W}{l}(l-x)=\text{eq. of L C}\\ T&=\frac{W}{l}x \quad\ =\text{eq. of A L'}\end{aligned}\right\} \qquad (48)$$

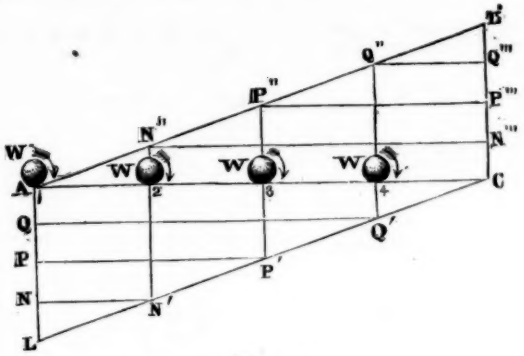

FIG. 42.

Turn the triangle A L′ C down for convenience, as in (Fig. 43), and then the shearing stress to be provided for is given by the figure A L P L′ C. In this figure A L = C L′ = W and $D P = \frac{W}{2}$.

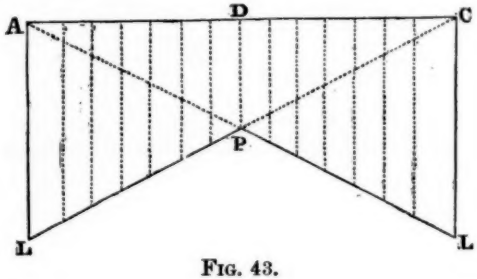

FIG. 43.

Case VI.

A distributed moving load. When a moving load gradually covers a beam, (Fig. 44), moving on from one end as a long train of cars, the maximum moments produced is that due to the load

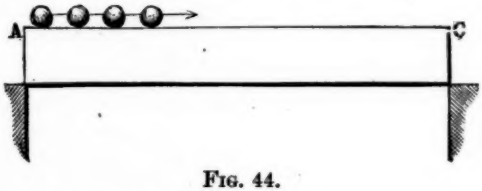

FIG. 44.

when it covers the entire length of the beam, and consequently this case is provided for in *Case IV.*

But with the shearing stress it is different. Here, as in *Case V.*, we need the *locus* of the greatest shearing stresses that can be brought upon the beam. This maximum at any section D occurs when the longer segment into which D divides the beam is loaded, and the other is not. In that case the shearing force at D (=the reaction of the abutment C) is

$$T = \frac{w x^2}{2 l} \qquad (49)$$

This equation gives the parabola A N P′ (Fig. 45) with vertex at A, where $C P' = \frac{w l}{2}$. When the load comes from

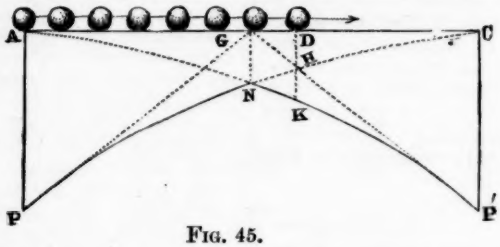

FIG. 45.

the other end of the beam we get the parabola C N P. Hence the figure A P N P' C gives the maximum shearing stress to be provided for.

It is easy to see that the shearing stresses thus obtained are greater than those which exist when the load covers the entire beam. In the latter case the forces are represented by the triangles A P G and G P' C (Fig. 45), the shearing stress at D being given by eq. (39)

$$T = w x - \frac{w l}{2} = D H$$

In the case of the passing load we have just seen that

$$T = \frac{w x^2}{2 l} = D K$$

The value of D H is always less than that of D K when $x \geq \frac{l}{2}$; for if $2x$ be a certain quantity, then the product of the halves of that quantity ($=x^2$) is greater than the product of any other two parts (such as l and $[2x - l]$) into which it can be separated.

That is $x^2 > l(2x - l)$

$$\therefore \quad \frac{w x^2}{2 l} > \frac{w l (2x - l)}{2 l}$$

or $$\frac{w x^2}{2 l} > w x - \frac{w l}{2} \qquad (50)$$

In the expressions for the moment of resistance $M = \frac{1}{6} S b d^2$ the quantity denoted by S (= the stress on the outside fibres) varies directly as M. Hence, all the geometrical illustrations we have given of the *moments* may apply equally well to the values of S. The maximum moments give the maximum stress on the fibres, and indicate the points of rupture when the beam is loaded with its breaking weight.

ULTIMATE VALUES OF S.

If beams are loaded transversely until fracture takes place, the value of S or the stress on the outside fibre which exists at the moment of fracture, gives us a value for the tensile or compressive strength of the material according to the manner of rupture. If the beam yields by *tearing*, S gives us the tensile strength, if by *crushing* S gives the compressive strength. We readily obtain the value of S answering to the ultimate strength from any of the formulas under "Transverse Stress," by substituting given values for l, b, and d and the actual breaking weight for W.

But the tensile and compressive strengths of materials are also obtained by direct tension and compression, the force being applied in the direction of the length of the bars until rupture takes place.

If our theory were perfect the values of tensile and compressive strength thus deduced would agree with the ultimate values of S found in transverse stress; but they do not.

The difference is very wide sometimes. Thus in cast-iron, S (in this case it represents the tensile strength) derived from breaking rectangular beams by a transverse load is nearly 20 tons per square inch, while the tensile strength obtained directly is only about 8 tons. This discrepancy has been accounted for in two ways.

1. That the neutral axis moves towards the compressed side, and that therefore a larger portion of the beam is subjected to tension than the formula supposes.

2. That the neutral axis always remaining at the centre of gravity of the beam, the additional strength is due to the *adhesion* of the fibres which is developed by the unequal lengthening, and shortening of them as we go from the neutral

axis towards the surfaces. In favor of this view is the fact that we know such adhesion to be an element of strength; for the compression or extension due to a given force is not so great in a transversely loaded beam as in one directly compressed or extended.

The action of this adhesive force may be illustrated as follows :

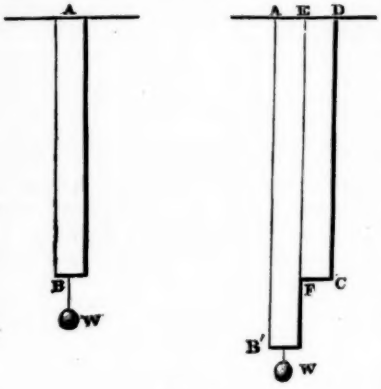

FIG. 46.

In the beam A B (Fig. 46), strained by the weight W, all the fibres are equally elongated, and they only resist by their direct tenacity. But in the beam A′ C to the one-half of which is appended the weight, while the other half, E C, is less strained or altogether prevented from extending, evidently W will have to overcome not merely the tenacity of the fibres in A′ B′ but the adhesive force of the fibres along the plane E F, where the two parts of the beam join ; for this force will tend to prevent the stretching of the fibres in A′ B′, and consequently increases the strength of A′ B′. This kind of force exists between every two layers of horizontal fibres in a beam under transverse loading, and is called the *longitudinal* shearing stress. It is neglected in the formulae we have given.

From the variation between the ultimate valves of S (called *moduli of rupture*) and the values for strength obtained by direct tension and compression, it results that the values should be determined in both ways, and that the values gotten by one method should not be used in calculations involving the other kind of stress.

BEAMS OF UNIFORM STRENGTH.

As already stated, in solid rectangular beams, S has different values for the various points in the length of the beam. There is always a point of maximum stress where the beam, if loaded sufficiently, will break. Now at all other points there is an excess of material which is useless and injurious from its own weight. To secure the requisite strength with the least material is an object usually desirable, and this can be readily accomplished in certain materials (as cast-iron), by giving the beam such a shape as will make S, the stress on the outside fibre, constant throughout its length. In wood the injury resulting from the cross cutting of the fibres frequently prevents the putting of the theory into practice.

The application of the theory of uniform strength to beams of *rectangular cross section* may be most simply explained by taking up the cases we have discussed in detail.

In *Case I.* from eq. (5) the maximum stress in the outside fibre is,

$$S=\frac{6\,W\,l}{b\,d^2} \qquad (51)$$

This stress only occurs at A, where the beam will ultimately break, and it is evidently possible to take away some of the material between that point and

FIG. 47.

C without diminishing the strength. If this be so done that at every point between A and C there shall exist on the outside fibre a stress equal to that at A, the beam will be one of uniform strength, and we shall have attained the greatest economy of material. Let us suppose, the use we have for the beam requires the depth to be uniform. What must be its *plan* in order that S shall be constant in value, or the beam be as liable to break at any other point as at A?

In eq. (4) $S=\frac{6\,W\,x}{b\,d^3}$, if we assume S to be constant, the other side of the equation must be constant also, and since 6 W is constant, and we have made d constant by assuming the depth to be uniform, the whole expression can be constant only when b varies as x.

$\therefore$ $b \propto x$ whence $b=c\,x$ (where c=some constant factor). This equation which is that of a straight line shows that the breadth must vary directly as

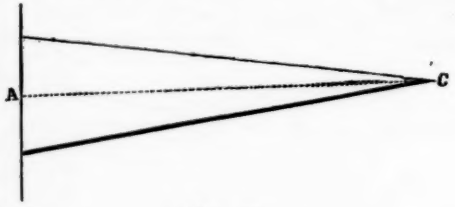

FIG. 48.

the length. Hence the *plan* should be a triangle with vertex at C (Fig. 48.)

On the other hand, if we suppose the breadth to be uniform and wish to have S constant, in the eq. $S=\frac{6\,W\,x}{b\,d^3}$, x must vary as d^3, or

$$d^3=c\,x$$

This corresponds to a parabola, and the beam, if the top be straight will have the *elevation* shown in (Fig. 49).

Suppose that b varies as d, then $d=n\,b$ (n being a constant) and

$$S=\frac{6\,W\,x}{n^3\,b^3}$$

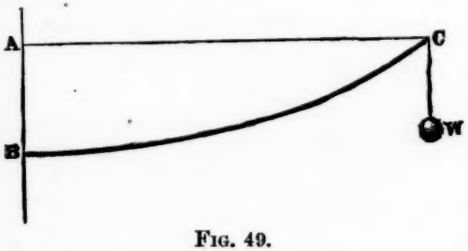

FIG. 49.

To render S constant we must have, $b^3 \propto x$ $\therefore$ $b^3=c\,x$ and $d^3=n^3\,c\,x$.

These are the equations of a *cubic parabola*. Hence the horizontal section (Fig. 50), and the vertical section (Fig. 51), should be curves of that kind. The

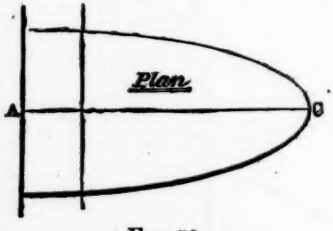

FIG. 50.

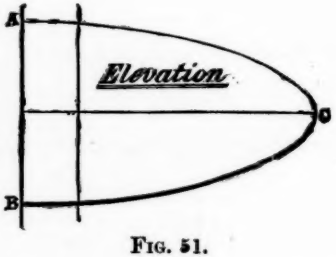

FIG. 51.

cross section is rectangular as in (Fig. 52).

In *Case II.* we have

$$S=\frac{3\,W\,x^3}{b\,d^3} \qquad (55)$$

FIG. 52.

Hence, if we make suppositions similar to those above we shall have, when the depth is uniform (or d= a constant) x varying as b, or

$$b = c x$$

Hence the *plan* (Fig. 53) should consist of parabolas with vertices at C. If b be constant then

$$d^2 = c x^2 \quad \text{or} \quad d = \sqrt{c.\,x}$$

This is the equation of a straight line, and gives for the *elevation* the triangle (Fig. 54).

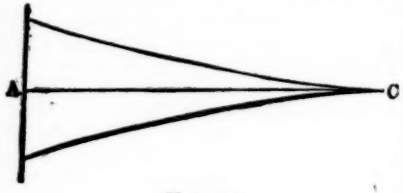

FIG. 53.

FIG. 54.

In *Case III.* the analysis gives results similar to those in *Case I.*

Thus from equation (21) $S = \frac{6\,W\,n}{l} \cdot \frac{x}{b\,d^2}$. Here $\frac{6\,W\,n}{l}$ is constant, and if d be constant also, b must vary as x.

$$\therefore \quad b = c\,x.$$

This gives the triangle A G H (Fig. 55). We obtain similarly the triangle G C H for the other end of the beam.

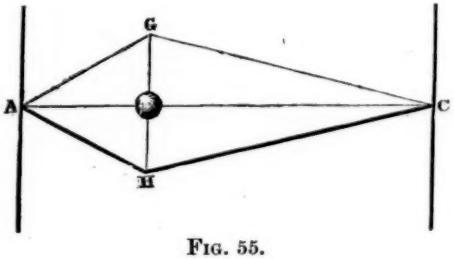

FIG. 55.

If the breadth be constant we have,

$$d^2 = c\,x$$

which gives a parabola AK (Fig. 56) with vertex at A. So, for the right hand end of the beam the proper elevation is the parabola C K (Fig. 56). The elevation (Fig. 56) assumes that the top of the beam needs to be horizontal.

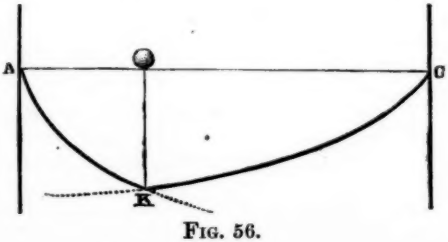

FIG. 56.

In *Case IV.*, equation (37) gives $S=\frac{3\,w\,x\,(l-x)}{b\,d^2}$: Here, if d be constant in order to render S constant we have

$$b=c\,x\,(l-x).$$

This may be represented by parabolas with vertices at G and H (Fig. 57) opposite the middle of the beam. If b is constant, then,

$$d^2=c\,x\,(l-x)$$

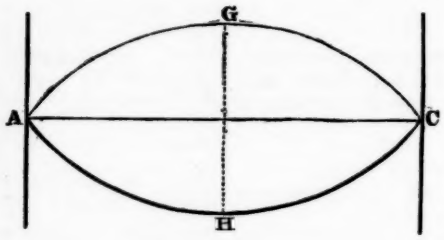

FIG. 57.

which is the equation of an ellipse, and the beam (if it is required to be horizontal on top) may be made as in (Fig. 58).

In these cases of beams of uniform strength, we have so far only considered the *moments* of the weights or the *bending moments* as they are called. But the

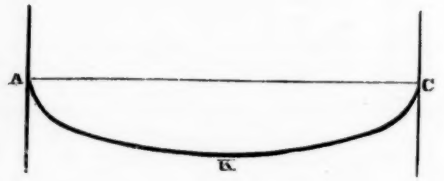

FIG. 58.

results are to be modified by the transverse shearing stress. In ordinary rectangular beams this shearing stress is so small compared with the bending moment, that it may be left out of consideration. But in beams of uniform strength the ends must not taper to a point, but must always be left large enough to bear the shearing stress. In the case represented in (Fig. 57) the beam should have, near the ends, the shape shown in (Fig. 59).

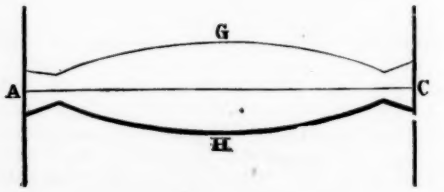

FIG. 59.

ON THE USE OF COIGNET BÉTON "*EN MASSE.*"

Condensed from Chief Engineer CHAS. K. GRAHAM'S Report to the "Department of Docks."

THE Canal Street section was commenced on the 4th of May, 1874, by driving piles for new Pier 34, the present Pacific Mail Steamship pier. It springs from the bulkhead wall, almost in a direct westerly line from the small pier formerly known as 42½.

The bulkhead wall on this section, 110 feet of which has been finished, foundation up to stone facing for a distance of 80 feet built, and pile work for 60 feet more ready for concreting, is a subject on which I will have to dwell at some length, as the method of constructing it differs materially from that used at the Battery and Christopher Street sections. At the latter works the system was—to drive piles, cut them off at a fixed distance from mean low water, and upon them to place prepared beton blocks by means of 100-ton derrick and divers.

On this section, as well as the King Street section, the piles are punched down, and loose concrete laid *en masse* in a false work of timber, which is subsequently removed.

That eminent authority, Mr. Thomas Stevenson, in his work on the "Design and Construction of Harbors," at page 201, says: "Sir John Hawkshaw has passed concrete through 50 feet of water with perfect success. As far as his experience went, the concrete set quite as well under these circumstances, as when it was deposited in the open air. He has done this both in salt and fresh water. In passing concrete through water, he used a box containing almost 2 cubic yards; when it reached bottom, a bolt was withdrawn, and the concrete dropped out."

The same authority, on page 202 of the same work, also says: "Mr. W. Parkes put in the foundation of the iron light-house in the Red Sea by means of a caisson into which the fluid concrete in bags was deposited." He thus describes the method of construction: "During this time some progress was made at the light-house works. The caisson of iron-plates to enclose the concrete base had been deposited upon the reef, where it was exposed to a wash sufficient to remove some of its clayey particles, without carrying it out of reach. As soon as a sufficient quantity of gravel was accumulated, the process of depositing the concrete was commenced. As circumstances did not admit of the usual plan of depositing the concrete in the water in large masses from boxes, the following plan was substituted: Sheets of tarred canvas were prepared of such sizes as would fill up the spaces between the piles, and allow 2 feet round each side, to be turned up, so as to form large shallow bags. The edges of the tarpaulin were then lashed to the wooden rods, which were slung to the piles, so as to allow the tarpaulin bag to float slackly on the surface of the water. Two or three hours below low water the work was commenced. The concrete was mixed in the lighters moored alongside the caisson—6 measures of gravel being used with one measure of cement, and a suitable quantity of water. The materials were thrown into the centre of the canvas bag, which gradually sunk to the bottom (generally from 1 to 2 feet under water), and the bag was spread out evenly over the whole area as it became filled. This was continued until the tide rose nearly to the level of the top of the deposited concrete, when the sides of the tarpaulin were drawn close over the soft mass, and lashed tight. In this way blocks of from 6 to 14 tons were deposited without the material having been subjected, in small quantities, to the action of the water. The blocks were generally hard enough on the following day to allow of the exposed parts of the tarpaulin being cut away; and so complete was the set, that casts of the cords and the edges of the tarpaulin were often sharply impressed upon the face of the concrete."

At the Canal Street section, the joints of the caisson were so close, as to admit of scarcely any wash, and being in a slip with block and bridge piers on either side, the current was scarcely perceptible, consequently when the concrete was

deposited, little more "laitance" or milkiness was visible than would have been occasioned if fresh made beton blocks prepared on land had been immersed in water. That eminent marine engineer, Sir Charles Hartley, in his valuable report on the "Delta of the Danube," at page 39, says: * * * "and the absence of divers to execute the work, induced the author, at first, to adopt the plan of building the wall on a roughly leveled foundation, by carefully lowering down masses of unset concrete within movable timber dams, fitted in lengths of from 15 to 30 feet, to the framework of the piers. This plan was not adopted on a large scale, until it had been found, by repeated experiments, that the concrete, when made with a sufficient quantity of Portland cement, set perfectly hard on a rocky foundation in a seaway, although lowered through the water in a semi-liquid state."

In passing the cement through the water at Canal Street, two separate one-yard tubs were used, and the concrete mixed was comparatively dry and far from a semi-liquid state.

At page 41 Sir Charles further says: "The spaces between the beton blocks used were filled up with newly made concrete, which, searching its way under the adjacent blocks, and filling in the grooves, moulded in their sides expressly to this end, caused the whole mass to become ultimately as solid as if it consisted of but a single stone."

As to the strength of the Portland cement used, Sir John Coode, in his remarks from Hartley's description of the "Delta of the Danube," at page 74, says:

"The cement was tested by Grant's machine to resist a tensile strain of 350 pounds per square inch, after being immersed in water 7 days. He had made large quantities of cement in mass under water and at a considerable depth, with the proportions of 1 of cement to 5 of gravel; he had executed a large amount of such work for some years past, and had built a substantial sea wall to the height of 40 feet upon it."

The proportions used at Canal and King Streets are almost identical—1 of cement, 2 of sand, and 5 of broken stone. At page 76, same work, Mr. Coode says: "He had lately put down some foundations for a heavy sea work on a rough, rocky surface, where, if he had not deposited the *concrete in mass* upon the rock, the expense of preparing the bottom to receive the blocks would have been somewhere about twice or three times as great, and the time occupied would have been three or four times as long as was required to execute the works by means of concrete deposited 'in situ' upon the bottom in 16 feet of water at the lowest spring tides."

I further give some excerpts taken from the reports of the Institute of Civil Engineers, London, Vol. 1862–3, a paper by Daniel Miller, C. E., entitled "Structures in the Sea without Coffer Dams:"

"The system of building under water by means of diving-bells and diving-dresses has been practised to a considerable extent; and the improved apparatus, now used, gives great facilities for this kind of work; but it is only applicable under particular circumstances, and it is also *costly*, besides being liable to cause delay in the progress of the work."

"There are three modes in which concrete may be applied for constructive purposes — building it in mass and allowing it to set before water has access to the work, as has been adopted in the construction of the walls of the Victoria Docks by Mr. Bidder, and in those of the London Docks by the late Mr. Rendel—preparing it first in blocks and allowing it to harden before being used, as employed by the late Mr. Walker, at the Dover Breakwater, and by Mr. Hawkshaw for the new sea forts for protecting the arsenals of Plymouth and Portsmouth—and depositing it in a liquid state, and allowing it to set under water, as practised upon a gigantic scale by Mr. Noel in the construction of the large Government Graving Docks, at Toulon. In the latter case, hydraulic concrete has been deposited in a liquid state in the sea water at a depth of about 40 feet, forming a vast rectangular trough of beton about 100 feet wide, of the length of each dock respectively, and with walls and bottom about 16 feet thick."

Speaking of the various kinds of hydraulic limes, Mr. Miller says: "It may be useful to mention, for comparison, the proportions of some of the concretes made from these various limes. The

Arden lime concrete employed by Messrs. Bell & Miller for the foundations of the large Graving Docks at Glasgow was composed of 1 part of ground Arden lime, 1 part of iron mine dust, and 4½ parts of gravel and quarry chips. The *lias concrete* used at the recent extension of the London Docks by Mr. Rendel consisted of—1 part of blue lias lime to 6 parts of gravel and sand. The proportions adopted for the blocks of the Mole at Marseilles were 2 parts of broken stone to 1 of mortar, the latter being composed of 3 parts of Tiel lime to 5 of sand." * * * * * "The Portland cement used at the new Westminster Bridge is harder and more compact than the greater number of building stones, even where put down in the bed of the Thames, and where it is exposed to the running stream." * * * "The author had lately an opportunity of examining at Genoa the extension of one of the Moles of the *harbor*, the inner side of which has a vertical wall."

"The latter was in process of being constructed *under water* entirely of pozzuolana concrete, simply thrown into the sea from baskets, carried on men's heads, a boarding confining it to the shape of the wall. In a short period it set quite hard, so as to enable the upper part of the wall, which is of stone, to be built on it." * * * * * * "Though the depth of the quay wall was not great, this shows the confidence which the Italian engineers have in concrete applied under water in a soft state. The piers of the new basin constructed by the Austrian Government at Pola, in Istria, are also formed in a similar manner, of concrete, confined between rows of timber piling. But perhaps the most striking application on a large scale of pozzuolana concrete, is in the great Mole which protects the port of Algiers. To form the Mole, blocks of beton of immense size, so as to be immovable by the force of the sea, were employed, some of these formed '*in situ*,' by pouring the concrete into large timber cases without bottoms, sunk in the sea in the line of the Mole."

"Hydraulic concrete, to be effective, requires great care and attention in its manipulation and in the regulations of the proper proportions of its materials."

"*Any failures must have arisen* from inattention to these or similar points, as there is ample experience to show, that when properly made, every confidence may be placed in the strength and durability."

In the construction of the Albert Harbor, Greenock, the following occurs, same authority: "The mode in which the work was designed was to form the walls under low water, of a combination of cast-iron guide piles in front, with a continuous stone facing, slid down over and inclosing these, and of concrete backing deposited in a soft state, all of which could be easily accomplished from above the water line." * * * * This plan was felt to be so novel, particularly as regards the concrete, that, though the trustees as a body had the greatest confidence in the engineers (Messrs. Bell & Smith), they considered it to be their duty, before proceeding with the work, to fortify themselves by having the opinion of another engineer; accordingly Mr. Thomas Page, M. Inst. C. E., was consulted, who fully satisfied them as to the efficiency of hydraulic concrete applied in the manner proposed, and otherwise confirmed the soundness of the principles upon which the works were designed.

Again, same authority: "Immediately after being mixed, and when brought to a proper consistency with water, it is conveyed to where it is to be used, is let down under water in the discharge boxes, and in a short time sets very hard. * * * This mode of constructing walls in deep water, without coffer dams, has proved very successful, and a sea pier of great solidity and durability has been formed at a comparatively moderate cost." * * *

"Temporary sheet piling or boarding, instead of loose stone, may be employed to keep the concrete in its place until it has set."

General H. G. Wright, of the United States Engineers Corps, an officer of great experience, in a letter addressed to Major-General Hamilton, late Superintendent in Charge of Yards, on the subject of Rosendale cement, among other things, says: "Of this cement I used some 50,000 bbls. in the fort at the Tortugas, a large part of which was for foundations and walls under water; the particular blocks to which I referred

were laid to test *the workings of the tremie.* * * * * They were laid in 1848, I think; and when I left in 1856, they were in as good condition as when laid, the surfaces being apparently as perfect. The concrete was made with sea water, no fresh water having been used."

In a subsequent statement, more particularly on the working of the *tremie system*, made lately, that eminent officer said: "The success attending (the above) induced him to construct the foundation of several of the forts in Southern waters in a similar manner, and with like success."

Forts Jefferson and Carroll he cited as prominent examples. "* * * * Should not hesitate to construct foundations under water, by depositing liquid concrete *in mass*, if care was taken in its manipulation."

Besides the valuable experience of General Wright, as above detailed, to my own knowledge mass concrete has been used in this country in the construction of foundations below water for a period of twenty-five years at least.

While Engineer of the Brooklyn Navy Yard I constructed a wall *en masse*, which is a standing witness to-day of the success of the system. My predecessor in office there used somewhat similar means. Mr. McElroy's wall at the Wallabout would have proved a success if attention had been given to the placing of more piles in the foundation, and had the Rosendale cement used, retained its previously high character, and not deteriorated in its tensile strength.

I will now briefly describe the method of placing this mass concrete *in situ* on the works in question.

The wall, up to within $2'\ 2\frac{7}{16}''$ (two feet two and seven-sixteenth inches) of mean low water, is made of a huge monolith of concrete *en masse* manufactured on the spot and deposited *in situ.*

The site for the wall was first thoroughly dredged to a mean depth of 20 feet below mean low water; piles were then driven, 8 in a cross section of 17 feet 6 inches, and of an average distance of 2 feet 6 inches from centres, except the two front rows, which are centred two feet; longitudinally the outer and inner rows were driven as close as could be done without interference; they were punched to about a mean distance of 13 feet below mean low water, by means of a heavy oak follower 26 feet in length and 12 inches in section, armed at the bottom with an iron pintle and banded with iron to strengthen against fracture; this punching obviated the cutting off of any other than the westerly row, and those only for a distance of 180 feet; this uneven punching afforded a good grasp to the concrete around their heads. Broken stone, measuring about 4 cubic inches, was then filled in between the piles and allowed to take a bearing. The false work for receiving the concrete was then erected. Yellow pine square piles, 12 inches by 12 inches in section, and of an average length of 40 feet, were driven in front of the westerly row of punched piles at a batter of $1\frac{3}{4}$ inches to the foot, and on the back at a batter of $\frac{1}{4}$ inch to the foot, centred longitudinally 8 feet; to the inside of these square piles, previous to their being driven, battens of 4 inches by $2\frac{1}{2}$ inches spruce were nailed on firmly, and on these further pieces of spruce, 12 inches by 2 inches, were fastened, forming grooves for receiving constructed wooden shutters or gates which were slid into place after the pile alignment was perfected. These piles were then capped crosswise by square 12-inch timber, braced laterally by waling pieces $12'\times 6''$, and on these cross caps stringers were laid, on which were placed rails of flat iron to receive the wheels of a movable platform car, bearing on it a 10 horse-power engine for the lowering of the concrete into the caisson. This platform car had erected on it a gallows frame holding traverse wheels with pendant bales of iron, from which were suspended double block purchases for the lowering and hoisting of two separate 1-yard buckets, each working from a separate drum independent of the other, so that one bucket could be lowered while the other was filled.

The concrete was mixed on a platform in the rear, constructed on the stay piles driven in the rear of the wall, wheeled to the car, dumped into the buckets or tubes, and then lowered into the caisson. The door of the bucket being opened from above by a trap rope, did away with the necessity of employing divers, and the only occasion when divers were

used at all was when Mr. McDonald, foreman of masons, himself a practical driver, leveled off the top layer of concrete to receive the granite facing. The buckets could be shifted from above in such a manner as to command any portion of the bottom.

The proportions of the concrete varied occasionally, but the usual proportions were, as before stated, 1, 2, and 5, or 1 part cement (Portland), 2 of sharp sand, and 5 of small broken stone.

Concreting was commenced on the 24th of December last and continued until the 6th of January, 1875, a layer of two feet being spread over the bottom, soaking into the broken stones at the bottom, and binding the pile heads firmly together. The quantity of ice by this time proving very troublesome, concreting was suspended until the middle of March (though further piling for the wall was continued throughout the winter, with scarcely any intermission), and vigorously prosecuted until the end of April, when the whole mass necessary was placed. In the hearting of the caisson, one-fifth of granite spawls, from the Departmental Stone Yard, were placed and thoroughly grouted, preserving the stability of the wall and lessening the expense.

In placing the concrete in water, chilled sometimes to 3° colder than the freezing point of fresh water, some means had to be adopted to counteract its chilliness. That eminent and versatile engineer, Mr. Chanute, in his report on the Kansas City Bridge, says:

"Both masonry and beton were laid in extremely cold weather, the use of hot sand and water being found to make this practicable. The sand was heated in large sheet iron braziers, and the water warmed in cast-iron kettles, one of each being found sufficient to supply the force working on a pier. The heat which was thus artificially given to the mortar hastened its setting, causing this to take place before the mass had cooled enough to make freezing possible."

Mr. T. C. Clarke, in his able and exhaustive report on the Quincy Bridge, says:

"During this time the glass fell as low as 16° Fahr. A shanty was built on a flat, and in this a kettle was placed on a stove, and the cement mixed with hot water. During the coldest days each stone was, before being set, held over a brazier of charcoal to draw out the frost. The mortar was examined carefully in the spring, and found to be as hard and perfect as any on the work. Much of the masonry of this bridge was constructed during winter, although none in as cold weather as this pier, *and there is apparently no difference in the quality of the mortar* whether built in *winter or summer.*"

As the quantity of cement used by these gentlemen was very small in comparison with that which would have to be used in the bulkhead wall in question, some means had to be taken of a more extensive nature. For heating the water, the following simple apparatus was used. A cask capable of containing 60 gallons of water, holding a coil pipe, was placed on the movable car, and through this coil the steam from the boiler of the engine was passed at will; this heating was done very rapidly and efficiently, it only taking from 4 to 8 minutes to heat the whole 60 gallons from 32° to 100° Fahr., the water thus heated being carried to the mixing platform by india-rubber tubing. To heat the sand and broken stone, heaters made of iron, similar to those used in street paving, were constructed by Mr. Joseph Edwards, 414 Water Street, New York, each capable of heating a cubic yard of material, the fuel used being old barrel staves, &c. They did their work thoroughly, and by this means work was carried on, on one occasion when the temperature of the air was 11° Fahr. and that of the water 32°, the concrete becoming as hard as if made during the hotter summer months, thus practically substantiating the opinions of Messrs. Chanute and Clarke.

In laying the backing to the granite facing I have introduced a change from that at Christopher Street section, which has materially lessened the expense, while preserving the stability of the wall. Blocks of about three cubic yards capacity were made at the Seventeenth Street yard out of old granite spawls and Portland cement; when sufficiently compact they were transported to Canal Street, and placed in position with great rapidity, over 70 lineal feet being laid during one tide. The success attending the use of these rubble blocks has been

such that I have recommended to the Board in my report on the "Development of the Harlem River and Spuyten Duyvil Creek for Commercial Purposes," that the bulkhead wall when constructed should be composed of beton placed *en masse* with a rubble masonry facing surmounted by a granite cope.

On the removal of the shutters and square piles—the false work of the caisson—which had been down nearly three months, Mr. McDonald carefully examined the sides of the monolith and reported that he found it as smooth and compact in appearance as any blocks he had ever seen which were manufactured on land—and no sign of honey-comb. This assertion was verified by my assistants, who passed a boat hook all along the sides both front and rear, and found it as smooth as the Gansevoort Street manufactured blocks; the edges of the "berme," too, 6 inches in width where the stone facing springs from the monolith of concrete, was as distinctly defined as that of a well cut piece of granite. A great saving has been effected by this system of construction, over that of the block system, including coping not as yet required on this section (the wall constructed being in the wake of the pier); the saving amounts to $67.77 per foot run, or over $350,000 per mile, the cost per foot run being $311.67.

By having a long stretch of work, a judicious use of labor, and using made rubble blocks surmounted by granite scope, instead of cut facing, I am of the opinion that the cost can be reduced at least 20 per cent

* * * * * *

Since this report was written, the Canal Street section has been extended about 200 feet, the short section at the foot of King Street completed, and a new section commenced at the foot Clarkson Street. The plan of construction being in every case precisely similar except on the Clarkson Street section, where it has been deemed advisable, in consequence of the great depth and softness of the mud, to drive the two front rows of piles with a batir of 1¾ inches, instead of perpendicularly, as on the other sections; the object of the change being to oppose still greater resistance on the part of the foundation to lateral pressure, and to enable the mould boards to be slid down further, so that the concrete may bind the pile heads to a greater depth.

The advantages of the beton "en masse" system are:

1st. As many sections as the Department deem advisable can be in course of construction at any one time—the distance between the old piers enabling the work to be prosecuted in the slips without any serious hindrance to commerce.

2d. The work, by the adoption of the heating process, as applied to water, sand, and stone, may be prosecuted at least during nine months out of the twelve.

3d. Unskilled labor can replace to a very great extent the skilled labor required under the block system.

4th. The new piers being differently spaced from the old, these new piers may be projected from the new bulkhead wall and completed in a great many instances before it becomes necessary to remove the old ones.

5th. The rapidity with which the work may be prosecuted and the immense saving in its cost.

THE DRAINAGE OF THE THAMES VALLEY. The City Solicitor announced to the Hampton Wick Local Board that a letter had been received from an inspector of the Local Government Board, stating, in reference to the subject of a combination of sanitary authorities in the Thames Valley for the purpose of carrying out a joint scheme of sewerage, that it was proposed to hold a conference in London, and asking that two or three members of the board might be named as delegates. Messrs. Frere & Co., of Lincoln's Inn Fields, had also written, stating that they were instructed to take proceedings against the Local Board of Hampton Wick for a disregard of the notice to discontinue the flow of sewage into the river Thames. Mr. Nelson thought this letter from Messrs. Frere could not have come at a more inopportune moment, and suggested they should be informed that a commission was issued by the Government, and that under the circumstances the Conservators had better abstain from any proceedings, which the board were prepared to meet.

NEW MATERIALS AND RECENT INVENTIONS CONNECTED WITH BUILDING.*

From "The Architect."

The subject I have the honor of introducing to your notice is necessarily full of details, and when once we have plunged into these it is not likely we shall be able to quit them for generalities. I therefore ask you to permit me to lay before you such general considerations as seem to belong to it now at the outset, rather than to reserve them till the close of the paper.

The first remark that will occur to most observant men is, that the building art, as conducted in England at the present day, presents fewer novelties than almost any others of the leading technic processes. Steam, electricity, and the progress of mechanical inventions and chemical research have revolutionized most of the great divisions of human industry. Sometimes it is a new method of manufacture which has supplanted an old one—the material remaining unchanged. Sometimes the old material has given way to a new one, and not unfrequently both material and method are alike revolutionized by discoveries made through that restless and eager spirit of inquiry and invention which is perhaps the chief glory of the present century.

For examples of new methods of employing old materials, we may turn to the principal fabrics used in clothing. Wool, flax, cotton and silk, are what they always were; but spinning, weaving, dyeing and ornamenting, which once were handicrafts, are now mechanical processes carried on by steam machinery in vast factories. Printing is another example of the same change; paper, ink and type are still employed, but the contrast between the handpress—which within the recollection of many of us was the only method in use—and one of Mr. Hoe's magnificent steam machines is enormous.

Of new materials which have supplanted or supplemented old ones, a very long list could be made out. One or two will suffice for the purposes of an illustration. Various grasses and other substances have now come into use either along with linen rags or as a substitute for them in the manufacture of paper. Stearine and various similar products have almost displaced wax, spermaceti, and even tallow as material for candles. Mineral oil has largely displaced fish oil. We are using stamped and printed paper for window curtains, and printed cloth for embroideries, German silver instead of plate, and papier mâche in place of wood; and in a hundred other instances the craftsman has a constantly increasing series of new substances placed within his reach by the scientific discoverer.

The most remarkable cases of all are, of course, those where material and method are both alike new, having either been called into being to supply some new want, or else presenting themselves with such capacities for being useful or pleasant inherent in them, that a want has sprung up, after the power of supplying it was acquired. All the applications of photography, of the electric telegraph, of the spectroscope, and of our amazingly enlarged chemical knowledge, seem to belong to this head. Till we knew we could have them our wildest dreams never led us to desire such things as photographs of our friends, or telegraphs from them when at the antipodes; and such contrivances as the sewing machine, such materials as gutta percha, or such inventions as the locomotive, have brought into existence a whole range of new requirements, which the world had never dreamed of till the power of supplying them was called into existence.

Building, compared with such matters as locomotion, the manufacture of clothing, or the transmission of intelligence, is an art which has changed wonderfully little, so little indeed that I am sometimes tempted to believe that there still remains open to some inventive genius among ourselves, the possibility of effecting something like the revolution which Arkwright commenced for textile fabrics, when he applied steam power to spinning. It is, of course, natural to say

* From a paper read before the Royal Institute of British Architects, by Mr. T. Roger Smith.

that it cannot be done; but the same thing might have been said beforehand of all the great steps which handicrafts have taken, and we might, I believe, do worse than entertain very seriously indeed the possibility of adapting machinery, mechanical processes, and novel combinations of material to building, on such a scale and in such a way as to cheapen the cost of simple plain structures to a great extent. This subject would land us at once in a region of speculations which might prove of practical advantage, and to us I confess the subject is tempting in the extreme, but I have not any intention of inviting you to pursue it. If, however, a wholesale transformatian, such for example as would be effected were we prepared to abandon brickwork for concrete, and slates for felt, is not within our reach, there are available for use no small number of inventions, in which the progress of contrivances and discovery has told upon the resources at the builder's disposal; and it is some of these which we are to consider.

Granted, then, that there exist a certain number of novelties, my second preliminary observations must be directed to the position which the architect ought to take with regard to them. This is a question which has two sides. It may be said that the architect as the skilled, cultivated, and trained director of the work, is bound to know what is going on, to make himself familiar with the latest improvements, and to give his clients the benefit of his knowledge; in short, he is to be abreast of the building art in his own day, and is to show that he is solely making himself acquainted with each capital invention as it comes out, and to embrace every opportunity of using it. This is a position which has much to be said in its favor. And if men expect their doctors to know the latest medicines, and their lawyer to be acquainted with the most recent legislation, they may be excused if they ask that their architect shall be equally well posted. If, however, you ask your medical man whether if some new remedy of which you have heard is not said to suit your symptoms, he will probably reply: "Yes, but I doubt whether it would suit your constitution; the reports of its actions are by no means uniform or complete, and if you take it you will be trying an experiment." Your solicitor when you ask him to take proceedings under some new Act will, if he be prudent and honest, reply: "True, the language of the Act seems to fit the case, but it has not yet been tested before the Courts, and your case will be the one to fix the interpretation upon the language if you proceed under this Act; better be cautious."

In both instances the professional man, if he had no duties to his client, would be delighted at the opportunity of contributing to the fabric of professional experience an item possibly of much importance; the expense or distress of the process being borne by the vile body—or purse—of his client. But if he is true to that maxim of professional conduct—which I take to be a sound one, so long as it does not carry a man beyond the limits of honor and good faith—"do the best you can for your client"—the experiment is left for some one else to try, while better known and safer methods, supposing such to exist, are adopted, even if they be less brilliant. This I hold illustrates an architect's true position in regard to new inventions. He ought to make himself familiar with them all; he ought to neglect no advantage offered by them; but he has no business to try experiments at a client's expense. If this be true there are only three conditions under which an architect is at liberty to adopt a novelty. First—If it has been in some way put beyond doubt that the novelty will succeed; Second—If it is certain that received methods will not succeed, and the novelty offers a better chance; Thirdly—If the client, knowing that there is the possibility of failure, decides that the novelty shall be tried.

It may be said that these conditions very much limit the adoption of new inventions, and no doubt they do so; but I hold that our first duty as architects is to secure that our buildings shall answer their purpose, and that trying experiments in them is not justifiable except under conditions which either render failure impossible, or at least shift the entire responsibility on to other shoulders.

It now only remains to guard you and the readers of this paper against any

misconception as to its nature and scope. I do not claim to have hunted up and named all the inventions worth notice brought forward during the past few years. Still less do I claim to have selected the best. I shall not attempt to do more than to point out the directions in which invention has been chiefly exercised, and to give under each head a few specimens, selected not as the best but as the most convenient illustrations. The subject, thus looked at, seems to divide itself into (1) new materials, (2) new methods, (3) new structures, and (4) new appliances. New materials may include revived ones, and applications of known materials to new purposes. New methods refer to new modes of working, chiefly to the substitution of machinery for manual labor. New structures, hardly perhaps, need explanation, but must, of course, be understood as applying to structures of hitherto unknown sorts, and which from their novel nature are essentially new inventions; or new introductions. New contrivances will embrace those appliances which forms portions of our buildings, such as lifts, bells, or cooking apparatus; and also will include some few new combinations of building materials for special purposes.

New or Revived Materials.—of these the most important by far are iron and glass. The modern application of both to building has been well known to us now for a quarter of a century; in fact ever since the Exhibition of 1851 showed how rapidly and cheaply vast structures of iron and glass (the iron work being chiefly cast) could be erected, and how great a charm they possessed; and the applications of these materials have been numerous and varied. The leading principle upon which that building depended, and to which it owed both its architectural quality and its constructional success was the continued repetition of a small number of well-considered forms. Every pane of glass was of one size, and so upwards as far as possible. Every column was of the same length, and every girder was of the same span. This principle was adhered to in the design of the Sydenham Crystal palace, but it has been in some other instances over-looked.

An iron and glass building is no doubt not a very durable one, nor very weather-tight, and the expense of its maintenance will be considerable; but nothing is in first cost so cheap, and for the purpose of large gatherings of people, nothing so appropriate.

Treated in a different way, iron ribs, carrying some light filling in, which may be glass or wood, have enabled us, when we enclose enormous spaces in a more permanent manner, to roof them over. The great railway sheds, and such buildings as the Agricultural Hall, the British Museum reading-room, and the Albert Hall are examples of buildings having iron roofs of prodigious span. These are buildings such as, from time to time, come within the ordinary scope of an architect's practice. It is very desirable for us to obtain a familiarity with the principles upon which these roofs are constructed, as although it may be very wise to obtain upon them the assistance of an engineer, whose whole time is spent in working out the details of iron work, the architect will find that he is at a great advantage if he can design their general forms himself. All these applications of iron as a building material seem, however, to shrink into insignificance before Mr. Scott Russell's Vienna cone; but this has been so recently described here by the inventor himself that I need not do more than refer to it.

Other applications of iron to construction are so familiar that I shall hardly be justified in referring to many of them among new inventions. I may, however, allude to Phillips's girders, as a contrivance which is still tolerably new. These are built up, as you are aware, by bolting two rolled iron joists together, and sometimes four such joists are combined with plates in addition to their own flanges, into one large beam. It is not easy to see the scientific ground upon which this combination (which places a very large amount of material comparatively near the neutral axis of the beam) can be advocated, but there is obviously a good deal of simplicity and handiness in the combination, and it is said to have good practical qualities.

Messrs. Moreland & Son, who are well known as skilled in the application of iron to building purposes, have contrived a description of fire-proof construction, in which they imbed a kind of slight bow string truss in the concrete, which they

fill in between large girders. This constuction is so far different from ordinary fire-proofing as to deserve to be mentioned. It was employed at the St. Pancras Hotel, and appeared to me, when I saw it being fixed there, to offer considerable advantages.

The next material which I propose to notice is one which has but resently been introduced, and may fairly, on that account, lay claim to the title of a perfectly new invention. I refer to selenitic mortar, the invention of General Scott.

This mixture I shall, I believe, correctly describe if I say that it consists of the ordinary ingredients of mortar—namely, lime and sand, though the sand is in larger proportions than usual, with the additions of a small quantity of gypsum (sulphate of lime), intimately mixed with the lime. This mortar requires to be mixed in a pug-mill very thoroughly, and when carefully prepared, will be found to have acquired, to some extent, the properties of a cement, for it sets rapidly, and when set it is extremely hard and tenacious. It is to the admixture of the gypsum that the rapid setting is due, but perhaps some of the general excellence of the material may be owing to its having been better mixed than usual. The Albert Hall was the first large building in which this material was employed; and while that hall was in course of erection I had repeated opportunities of noticing its admirable behaviour. The London School Board have latterly adopted it throughout their new buildings, and probably their architects may have met with varying results, considering the various builders who have worked for them; but there can, I think, be no doubt that, on a building of any magnitude and under proper supervision, selenitic mortar will be found to be a trustworthy auxiliary to the architect. Of the use of the same material for plastering I cannot speak so fully.

The adaptation of concrete to building walls, floors, and roofs, as well as the foundations, may fairly claim a moment's notice. Tall and Drake are two names best known in connection with it. As far as I am aware the use of lime concrete, which involves walls, etc., of considerable thickness, has not been much pushed. Portland cement concrete, a stronger material, capable of being used on thin walls, and having the property of hardening very rapidly, is more commonly employed. The different patents have for their object, when walls are to be built, the construction of troughs by the help of frames and movable boards or shutters. These troughs are the exact size of the wall, and the concrete is filled into them. When the material has set the trough is taken to pieces, refixed at a higher level, and the process is repeated. I am not disposed to believe that much economy results from building in concrete, except where the work is very plain and straightforward, and when little is spent on subsequent finish; but there can be no doubt that a wonderfully strong and tenacious material is obtained; and probably where the foundation is unquestionable, the materials good, and the supervision during the progress of the work thorough, a stronger building is erected—and one more proof against the attacks of weather than if brick were employed—and at a not greater expense.

Allied to concrete is artificial stone, and this, with the various panacea for arresting the decay of building stones, has of late retreated to some extent from the public view. It is happily very difficult indeed to make bad stone into good, and consequently most of the solutions and washes which have that for their object have proved unsuccessful. Not that there are not many of them which have a sound scientific basis, but the difference is very great between treating a specimen of stone in the course of a well-arranged laboratory experiment, and treating similar stone, built into a wall, perhaps saturated with wet, and exposed to all vicissitudes of weather, in the rough way in which, on a scaffold, even careful workmen will apply, what they call chemical stuff; and we cannot wonder that solutions, which are theoretically excellent, have often in practice failed to protect masonry. The artificial stone of Mr. Ransome is, I think, the only material called artificial stone which has held its ground; and I believe that under his more recent patents an excellent and durable substance has been produced, but in many cases, not at such a price as has enabled it to displace natural stone for plain work. Where elaborate work, such as

would admit of being produced in a mould, has been required, this material has, I am informed, proved both economical and satisfactory.

Another material which (while it is incorrect to call it a substitute for stone) can often be adopted as an alternative material, is that very old form of brick, known as terra cotta, the use of which has revived to such an extent as to stimulate the manufacture. Although terra cotta is not a new material in one sense, it is so in another, for it is only very recently that it has become possible to obtain it in such quantities, and of such varied quality, that it could be readily adopted by the English architect. He who would employ terra cotta must submit to a certain amount of limitation; he cannot deal with it as freely as he can with masonry. He must design his ornament long beforehand; he must, if possible, arrange for a large amount of repetition; he must so design his work that, if slightly warped in burning, the effect shall not be entirely spoilt; he must prepare for delay and trouble, and he, or some one for him, must draw out all profiles, etc., to a sufficient scale to allow for their shrinkage. But subject to these and other minor conditions terra cotta is an admirable material. When used in large quantities it is cheap; it is very durable; it can be obtained of beautiful color and texture; it is the most appropriate material to employ along with brick, and it admits of the introduction of great richness, and of the indefinite multiplication of a few pieces of artistically modeled work. It is to be hoped that the Natural History Museum, where Mr. Waterhouse is employing it on an extensive scale, will give a great stimulus to its use. In the various buildings of the department at South Kensington and in the Albert Hall, terra-cotta has been extensively employed; and Mr. Barry's Dulwich College, and Mr. Christian's Insurance Office in Bridge Street, may be pointed to as other examples of its use.

Bricks themselves, and tiles have not furnished of late years many really new inventions. The damp courses, air bricks, shaped facing bricks, and roofing tiles of the ingenious Mr. John Taylor are, I have no doubt, known to all present. I do not recollect any other varieties of brick requiring mention here till we come to Pether's ornamental bricks, a variety available for use in surface decoration. These bricks have a pattern impressed on them, and being made of fine clay and well executed, have been often introduced lately into decorative work, and might with great advantage be more generally employed, as architects could readily design ornament appropriate to them.

The various sorts of flooring and encaustic tiles are no longer new, indeed they present one of the best possible examples of a new building material becoming generally so adopted as in a few years to grow perfectly familiar. A tile of German manufacture was, however, introduced into this country a short time ago which has not yet become very generally known; it is in large slabs, and rather delicate tones of color seem preferred, though very elaborate decorations have been executed in it.

A comparatively new mode of employing tiles for the lining of rooms have been introduced by Messrs. Simpson, who have decorated the interior of many parts of Messrs. Spiers & Pond's "Criterion," in this manner. The tiles are placed together in their unglazed state, and a picture is painted upon them in suitable colors for firing. They are then taken asunder and put into the furnace, and then subjected to great heat and glazed. If this is successfully accomplished, the tiles can now be fixed against the wall of the room and present an absolutely indestructible decoration, which can be washed as often as it is needed, though from its high glaze it is not easily apt to catch dirt.

Mosaic—the most ancient of all the arts of decoration—has a claim to be named among the revived processes if not admissible as a new one. I shall not attempt to describe Salviati's most praiseworthy revival of glass mosaic, which has placed in the hands of our architects a method of executing surface decoration which, ancient though it be, is, I think, really knew to Great Britain in its application to vaults such as the Wolsey Chapel, at Windsor, or the vault of the Albert Memorial.

Other descriptions of mosaic, however, especially tile mosaics, if less sumptu-

ous, are less out of reach, on the score of cost, and deserve our notice as affording a means of executing original decorative work at a distance from the eye as well as near. The ornamental frieze round the galleries of the Albert Hall, executed in tesseræ of about an inch square, is a good example. Here only two or three tints of color were employed, and the mosaics were rapidly made, after the full size cartoon had once been completed by placing the tesseræ on a tracing to a portion of the cartoon till a space of a certain size had been covered (about six superficial feet, I think) and then upon the back of the tesseræ Portland cement was applied till a stout slab was formed which admitted of being handled readily and could be hoisted up and fixed in place.

Another description of work approaching mosaic has been lately introduced to London, and is obtainable of Mr. Burke, of Regent Street—I allude to marble mosaic. This work is executed to a large extent out of smallish irregularly-shaped fragments of the material, of two or three tints, so laid as to produce the general appearance of a mottled ground, which gives relief to a few portions of brighter colors executed in more valuable marbles. When well done this sort of mosaic is very effective; it can be obtained at a very moderate price, and it may be expected to prove extremely durable.

We will now proceed to consider for a few moments the second head—new *methods*—not because the list of materials is exhausted, far from it; but because enough has been said to carry out my promise that I would name a few as specimens of the whole, in the hope that in the discussion your own sources of information will enable you to enlarge my list.

New methods need not detain us long. The building trade has not been revolutionized by the introduction of machinery as other trades have been, and it is really only in one or two of its branches that anything approaching to innovation awaits us. A remarkable attempt to introduce machinery into this production of high art work was made when the machines by which the woodwork of the Houses of Parliament was roughed out were designed. These, I believe, are now in the possession of Messrs. Cox & Son, and are still worked by them; but from various circumstances they do not seem to have become generally known or copied.

Machinery for dressing stone has been again and again attempted, and has been employed with considerable success. The contractor for St. Thomas's Hospital had a series of machines at work, partly employed in sawing up the stone and partly in dressing it; and one or two stone dressing yards exist, or did lately exist, where plain descriptions of work are performed by mechanical means. The action of such machines is, generally speaking, that they bring a series of chisels, or tools answering to chisels, forcibly down upon the stone so as to imitate the action of a mason at many points at the same time. Usually the chisels are carried on the periphery of a wheel, though different arrangements are adapted by different inventors. Probably sawing can be done better by machinery than by hand, as well as cheaper. The plain dressing of surfaces, and even the moulding of them, is within the reach of machinery, but it is doubtful if it will be so well executed as a good mason would do it, especially if the stone operated upon were of uneven or unequal texture, and the more elaborate the work or the fewer the repetitions, the less advantage, generally speaking, can be expected from the machine.

Joiners' work admits of the application of machinery to a larger extent than masons' work, chiefly, if not solely, because it includes so much more repetition. In a first-class joiner's shop you now find a very interesting and complete series of machines, which render it possible to diminish the labor on joinery very largely. It is hardly necessary to describe these inventions at length; they may be seen at work in the establishments of our large builders, and no one who has watched their operation can doubt their efficiency in all ordinary work.

Here, perhaps, I may most appropriately introduce a reference to the contrivances for testing materials, which supply us with information as to their strength and behaviour under different kinds of strain. We have now in Mr. Kirkaldy's large and accurate machine a

testing engine of a power practically unlimited, and accurate to the extent of making single pounds of pressure, while it will admit specimens as large as forty feet in length. Here, then, we have a means of investigating the strength of building materials such as has not been previously at our disposal, and we have only ourselves to thank if our knowledge is not extended thereby.

Our third head need not detain us long. New *structures* are not so often met with as that the enumeration of them should fill much space; and were we to attempt more than an enumeration, a single novelty would claim the whole time at our disposal. A railway station, a Crystal Palace, a modern hospital on the pavilion plan, a cottage hospital, a monster hotel, an aquarium, a winter garden, a model prison, a workhouse, a block of model dwellings, a board school—each of these is a new structure, each embodies very modern ideas, and each of them requires to be studied with some care before it can be safe for an architect to venture upon it, and each is in fact a new structure. And first, every such modern building as a market, a town hall, an exchange, or a court of law, built to serve the same purposes as ancient structures, must in the present day be much more perfect and much more elaborate than was formerly necessary, and is in effect an almost new contrivance.

A year or two back we were threatened with an importation of Swedish or Norwegian buildings, which, so far as their employment in this country is concerned, would be new buildings. I refer to timber dwelling-houses. The publicity given to Mr. Vicary's importation of a timber house, which he erected in Devonshire, turned attention to the possibility of building very roomy structures of wood at a low cost. I have no means of knowing how far this house has been copied, but it does not seem to have led to many such experiments, or some of them would have been pretty sure to become generally known. It is not easy to see why this build of house should not be followed in sheltered situations in this country. No doubt careful examination would show that it has drawbacks, but for use as a country resort, a shooting lodge, or a hunting box, a timber house properly constructed ought to be fairly comfortable and cheap.

This leads us to another attempt at importation, this time from our own colonies, and due to the ingenuity of Mr. John Taylor, whom I have already had occasion to name, as a building inventor. I allude to the bungalows which that gentleman has erected near Westgate, and at Birchington in the Isle of Thanet. I have had the opportunity of seeing these houses, and of examining one of them in course of construction. They are very simple in shape, mostly, but not always, one story high, spanned by a simple low-pitched roof, portions of which are prolonged in the true Anglo-Indian style to form a verandah. These buildings seem thoroughly well adapted to the purpose for which they are erected—that of summer sea-side dwelling houses; they can be worked and kept clean with a very small amount of labor, as many contrivances to diminish servants' work have been introduced, and they are evidently cheap to build, though tasteful both outside and in. For the purpose of these buildings Mr. Taylor has invented what may perhaps be called a water-proof wall. This invention has been patented by Mr. Taylor, who is willing to grant licences to those who desire to use it.

Other new buildings are to be found now about watering places where a public room, more or less resembling the établissement of a French sea-side town, is often now to be found, and where also an aquarium or winter garden, and a pier with a pavilion at its head is now *de rigeur*. As, however, the Committee on Sessional Papers will, without doubt, see fit to obtain a descriptive account of some, if not all these structures, they need not detain us at the present moment; and the same remark applies to that strikingly new construction which the Safe Deposit Company have engaged our Fellow, Mr. Whichcord, to erect opposite the Mansion House.

In conclusion Mr. Smith enumerated various new building appliances, and regretted that he had been prevented by want of time from procuring a larger number of specimens for exhibition. Before an architect used any new invention he would naturally first inquire—How it would go wrong; secondly, if it went

wrong what would be the worst consequences; and, thirdly, whether failure was preventible? Upon the question of repairs, he pointed out that it would not be a fatal objection to the use of iron shutters if the manufacturer's works were 100 yards off; but it would be intolerable if they had to be sent 100 miles when they got out of repair. The position of the architect with regard to the use of novelties was a very responsible one, and Mr. Smith explained that his review of a very large subject had necessarily been very partial and incomplete.

Mr. HEBB said that he had been asked to call the attention of the meeting to some specimens on the walls, and would apologise for not doing so, because the indiscriminate introduction of inventions was perhaps not desirable. In the present instance the exhibitor was not merely the owner but also the producer of the invention. The inventor, who lived in London, was a man of some artistic ability, and the process, which was called xylography, was somewhat similar to that called xylatechnigraphy, described in a paper recently read before the Institute by Mr. G. T. Robinson. By means of the peculiar nature of the ink employed the inventor obtained a cheaper impression than had hitherto been produced in wood.

Professor KERR, in rising to propose a vote of thanks to Mr. Smith, said that the subject selected was one upon which he thought it would be well if an annual paper were read. The public complained of the backwardness of architects in the introduction of new inventions, and he thought it would be good policy to meet such an objection in the mode suggested, as the difficulty he was convinced would not lie in finding material for discussion, but rather in confining the material within reasonable limits. The paper was very suggestive, and, like all that Mr. Smith undertook, was modest and unambitious: he knew where to stop. One thing, Professor Kerr said, he could not help observing—that although Mr. Smith began by saying, in effect, that building was making no progress at all as compared with the progress made in various other arts, yet in the course of his disquisition he proved that building was making very great progress indeed. This was sufficiently apparent to any one who looked back twenty or thirty years, and still more so to those whose memory could carry them back to a remoter period. Mr. Smith had referred to the use of iron and glass for structural purposes; and the extent to which those materials had developed in various departments was remarkable. At the same time, the crystal palaces built in various parts of the country, although works of great magnificence, could not, structurally speaking, be regarded as a great success. Great effects were no doubt accomplished, yet he did not think that architecture had, constructively speaking, very materially advanced by that invention. One matter well worthy of consideration was whether steam might not be rendered subservient to building processes. In his (Professor Kerr's) opinion the Vienna dome or Vienna cone) as it ought properly to be designated) was one of the most remarkable inventions of modern times—its marvellous simplicity was extremely interesting, and he would repeat what he had said before, that students of construction would be well repaid by mastering the principles involved in its construction. With regard to Phillips' girders he thought the invention was meritorious, and scarcely deserved to be passed over with the assertion that it consisted mainly in the accumulation of material at the neutral axis, because the simplicity of the girders, and the absence of riveting were most important features and worthy of careful study. As to the selenitic mortar, of which Mr. Smith spoke with much approval, it was rather a peculiar thing, and he believed that although General Scott was credited with its discovery, selenitic mortar was, in fact, based upon an invention of Mr. Westnacott—the only difference being that, for the purpose of expelling the carbonic acid from the stone, gypsum was substituted by General Scott for ground chalk. Upon the question of concrete he maintained that a concrete wall, as compared with stone or brick, was the only perfect wall we had; the only difficulties were in the successful manipulation of the concrete, and in making it air-tight. The wet might, he believed, be excluded from a concrete wall by the application of cement; and concrete should not be re-

garded as a substitute for brick and stone, but as something entirely distinct. Upon the interesting subject of artificial stone, the Professor said that he was glad to hear Mr. Smith touch. Ransome's artificial stone would probably have been much more extensively used if it had not been brought out at too high a price to admit of its competing with natural stone. The material was used extensively in America, but only to a very limited extent in England. The question of terra cotta had been dealt with very properly, but not exhaustively, by Mr. Smith. He (Prof. Kerr) thought that in designing terra cotta they should endeavor to accommodate it to the roughness of the materials with which it was associated, and he objected altogether to the principle of the indefinite of the reproduction of the same kind of forms.

Why should not terra cotta instead of being treated for the sake of obtaining an infinite reproduction of the same feature be handled with the tool in such a way as to procure much greater variety?

THE MAGNETIC IRON ORES OF NEW JERSEY—THEIR GEOGRAPHICAL DISTRIBUTION AND GEOLOGICAL OCCURRENCE.

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Transactions of American Institute of Mining Engineers.

The magnetic iron ores of New Jersey are found in the northern part of the State, in the Highland Mountain range, which runs from the New York line on the northeast, to the Delaware River, near Easton, at the southwest. The same range continues across Orange County to the Hudson River, and towards the southwest it is known in Pennsylvania as the South Mountain. It is more properly an elevated table-land, quite deeply furrowed by several narrow, longitudinal valleys, and shorter cross-valleys or gaps. The ridges or lines of elevation, as well as the lower valleys, conform in their general direction very closely to the general trend of the whole belt or table-land, that is, from northeast to southwest. This also agrees with the prevailing strike of the rocks. This great uniformity in the altitudes of the hills and ridges, and the direction of the lines of depression corresponding to the strike of the strata, point to an original table-land, which, through the long action of denuding agents, has been quite deeply eroded, giving rise to the present surface configuration, so that some of the former and uniform features have been partially obliterated. The very few cross-valleys or depressions are much more irregular in their course, and serve as outlets through which the drainage is carried either into the Kittatinny Valley on the northwest, or to the broad, red shale and sandstone plane bounding the highlands on the southeast. The area of this highland region in New Jersey is about nine hundred square miles. Its average elevation above the ocean is about one thousand feet.

Except the valleys towards the northwestern border, as the Wallkill, Musconetcong, Pohatcong, and German, which contain magnesian limestone and Hudson River slate, this whole range consists of crystalline rocks, mainly gneiss, granite, syenite, and limestone, covered in many places by drift and alluvial beds. These rocks resemble closely those of the Laurentian formation of Canada, both in their structure and mineralogical characters. Stratification is nearly everywhere plain, indicating a sedimentary origin and subsequent metamorphism. In the Geological Survey reports of the State they have been described as belonging to the "Azoic Formation."

It is in this series of crystalline, metamorphic rocks, that the magnetic iron ores occur. The extent of this outcrop and the iron mines and localities at

which ore in workable amounts has been obtained, are both indicated upon the geological maps of the State survey, one of which has just been published. This map shows the mines as in lines nearly parallel to one another, and having the same direction as that of the whole belt or range. In some instances they are so close as almost to form a continuous line, as the Mount Hope, Allen, Baker, Richards, Mount Pleasant, and others, near Dover, in Morris county. Others appear in a sort of *en échelon* arrangement.

This occurrence in *lines*, or what may be more properly termed *ranges*, is so well known that miners and those searching for ore speak of veins continuing for miles, and of certain mines belonging to certain veins. Large and productive mines, as the Hibernia, Mount Hope, Dickerson, Ogden, and Kishpaugh, with others, give names to such lines. The complete breaks in veins worked, and the absence of any indications of continuity, show that these popular theories are not yet substantiated by the facts, although, if by the terms *lines* or *veins*, or, better, *ranges*, series of ore-beds whose several lines of strike or axes run closely parallel to one another, are meant, then they have a foundation in truth. In the "Geology of New Jersey," published in 1868, the mines then opened were grouped in such lines, and these were called ranges. The map accompanying that report, as well as the one just issued issued by the State Survey, shows these lines and the intervening belts. A comparison of these two maps confirms in some degree this theory of ranges, or what would be better termed, ore-belts, inasmuch as the hundred or more new mines and ore outcrops opened since 1868, and represented on the latter map, are nearly all either on old and well-known lines or what must be considered as new ones. These discoveries have shortened the gaps and widened the ranges. Thus the new mines near Chester, and those along the eastern base of Copperas Mountain, all in Morris County, have filled in wide blanks, and greatly extended what were but very faintly indicated as ranges or belts of ore. The numerous openings quite recently made on Marble, Scotts, and Jenny Jump Mountains, in Warren County, constitute a new and marked line. In this the manganiferous character of the ore throughout its whole length seems to give additional evidence in proof of such a relation. An order of arrangement or division into such lines or belts, based upon lithological and mineralogical characters, has not been possible, but it is hoped that further studies will develop the existence of such characteristic features which will confirm the indications from the geographical distribution.

The last map also shows *groups of mines*, between which very little ore has been found. One of the best known and largest of these groups is near Dover, Morris County, and a map of this district was published in 1868. Northeast of this there is an interval of several miles, extending almost to Ringwood, in which there are no working mines, and comparatively but few localities where ore is known to exist. But the newly opened Board, Ward, Green Pond, Pardee, and Splitrock mines, show that the lines of ore are beginning to be traced into this hitherto barren district, and point to future discoveries which will connect the Ringwood and Sterling groups with the Morris County lines. A lack of cheap and ready transportation has prevented the thorough examination of this part of the State, or the development of any localities which were promising.

The extended workings in the older mines are also doing much to prove the great length, and probably continuity, of some of these veins. Thus the long run from Mount Hope to the Dickerson mine, a distance of seven miles, has been so opened as to show an almost uninterrupted bed or vein of ore, or a series of veins parallel to each other, and all within a very narrow belt; and all of the facts of geographical distribution, as well as the arguments which could be drawn from the probable mode of origin of this ore, tend to support this theory of *lines* or *ranges*, or better, perhaps, *belts* of ore.

Magnetite, as a mineral, is very common in the crystalline rocks of the Highlands, occurring more frequently than any other mineral, excepting the ordinary constituents of the gneissic rocks, viz., quartz, feldspar, mica, and hornblende.

And so widely is it distributed that it is impossible to find many strata in succession where it is entirely wanting. It appears as one of the constituent minerals of these beds, either wholly or in part replacing their more common components, or it is added to these, and in each case occurs in thin layers or laminæ alternating with them, or it is irregularly distributed through the rock mass. The unstratified granitic and syenitic rocks, as well as the bedded gneisses, also often contain magnetite. In these, however, it occurs in larger and more irregular crystalline masses or bunches, and does not appear to be so properly a constituent of the whole, but rather as foreign to it. The same mode of replacement is sometimes seen in these as in the stratified rocks. In both these classes it enters into the composition in all proportions, increasing in amount until the whole is sufficiently rich to be considered as an ore of iron. Between rock entirely free from magnetite and the richest ore there is an endless gradation, making it impossible to fix any other line of demarcation between them other than that of the minimum percentage for the profitable extraction of the iron. Three modes of occurrence have been assigned to this mineral, two of which are in the rock, as one of its constituents either in irregular bunches or in a granular form, and the third in *seams* or *strata*, when it is called *ore*. But these distinctions are not fixed, and therefore it is better to consider it as one of the more common minerals of these gneissic and granite rocks, and in places forming the whole mass, or else so much of it as to be workable, and then to be called an ore. Rock containing from twenty to forty per cent. of metallic iron, the most of which is in the form of magnetite, has been found in many places, and some of these have been explored to a considerable extent in searching for richer ores. The granitic and syenitic rocks containing magnetite are generally found to cut the beds of gneiss, and are, geologically, huge ore-bearing dykes. The most common mineral aggregation is feldspar, quartz, magnetite, and hornblende, or mica, although in some cases both the latter enter into the composition. Such rock is worked at a few points, but these operations are not yet worthy of the designation of mines. And, in fact, the great irregularity and the varying percentage of iron in it does not make it a desirable ore. Gneiss containing magnetite in quantity sufficient to render it workable, has been opened and mined at several localities. Perhaps it should be called *lean ore*. One of the most extensive outcrops of such ore is near the Pequest mine, in what is known as the Henry tunnel, about two miles north of Oxford Furnace. Here there is a breadth of twelve feet or more, in which the beds are highly impregnated with magnetite, while those on each side are free from it. Extensive drifting and sinking have exposed several hundred feet of these beds on the line of strike, and shown an increase in the percentage of iron going from the surface to the lowest levels. Near Hackettstown, in Warren County, there are several localities of such *ore-bearing* rock, but nearly all of them are failures as mines. The Scrub Oak mine, near Dover, the Combs mine, near Walnut Grove, the Swedes and Beach Glenn mines, also in Morris County, have large portions of their *veins* so mixed with rock that they may be classed with the above localities of *ore-bearing* gneiss. And all the lean ores of the State may be considered as gradations in the series from rock to what is conventionally termed *ore*.

While it is impossible to separate these lean ores from the rock upon any decisive or marked distinctions or differences, the richer ores are to be considered as a distinct mode of occurrence, as these differ from the lean ores and rock in their simplicity of composition, being made up of fewer elements, and these predominating to the exclusion of all others.

Assuming this as another mode in which the magnetite occurs, the geological features of these *seams* or *strata* may claim our attention.

They are often called *veins* because of their highly inclined or almost vertical position, and hence resemblance to true veins. Their irregular form has helped to strengthen this opinion of them. But as they show well-marked planes of stratification and also lamination, both parallel to the beds of gneiss which inclose them on the sides, and have strike, dip, and pitch, and are folded, bent, con-

torted, and broken, just as stratified rock, they must be called beds, and be classed among the sedimentary rocks. The irregularities in their extent, thickness, and the presence of included masses of rock, known as horses, are phenomena common to the gneiss and them, and therefore these cannot serve as an argument for calling them veins. Lenticular masses of micaceo-hornblendic gneiss, lying in feldspathic and quartzose beds, or the converse, are quite common, nor do the strata of these rocks run on unchanged in character. But they thin out or grow thicker, or change in mineral composition just as these veins are seen to *pinch out* or swell into thick *shoots*, or be replaced more or less gradually by rock. The similarity in these respects between these ore masses and the surrounding stratified rocks proves them to be beds and of contemporaneous origin. Imbedded in the gneissic strata of this highland belt or region, these iron-ore beds or veins (so called) have the same general strike or dip in common with them. The prevailing direction of the first is towards the northeast, varying, however, within the quadrant from north to east. In most cases it is between the north and northeast. From these there are several exceptions, as at Oxford Furnace, where the veins run north 25° west; the Connet mine, a few miles west of Morristown, where it is also northwest and southeast. While these lines of strike have a general straight bearing, they exhibit short irregularities and deflections, often varying from side to side, or zigzagged by faults or offsets. The rocks of this formation, as observed in hundreds of places, show the same prevailing straight lines as are seen in the longer openings for ore. Bends or foldings are very rare. One of the most remarkable of these is on Mine Hill, Franklin, Sussex County, although this occurs in a zinc vein or bed, and not in iron ore. Here there is a quite sudden bend, so that the vein returns almost to its original course—which is the usual northeast and southwest one. In the iron mines of the State, the Waterloo or Brookfield mine, about five miles north of Hackettstown, in Warren County, shows a curving strike—turning from northeast and southwest to north and south. Further opening may find as complete a bend here as is to be seen on Mine Hill. But the best example of such folding is at Durham, Pa., where the iron-ore vein, as followed in the mining operations, coincides in its course very nearly with the contour line of the Mine Hill, running around in a semicircle on the western side of this elevation.

The dip of these ore-beds being at right angles to the line of strike has, of course, the same degree of uniformity in direction, and that is towards the southeast; or more generally towards the east-southeast. In some localities the strata are in a vertical position or inclined towards the northwest, and the dip is in that direction. But this has been observed in a few mines only, and in some of these, deeper working has found the vein below assuming the prevailing southeast dip, indicating the existence of a fold, of which the *vein* opened is a segment, or a bending over near the surface caused by some powerful force acting subsequently to the elevating and folding agents. The Beach Glenn and Davenports' mines, in Morris County, offer illustrations of northwest dips. The rock outcrops show a number of such directions, but they are comparatively few in number, when the thousand or more observed southeast dips are considered. In the Connet mine (mentioned above) the dip is towards the southwest. At Durham it is radiating towards a central axial line of what is considered as a fold, and in, towards the centre of the hill. In the Hurd mine, as also at the zinc mine, Franklin, the two legs of the synclinals show dips at different angles towards the southeast, one of those at Hurdtown, being almost vertical, while the other is quite steep. In the large openings of the Ford and Scofield mines there is no dip, the beds standing vertical.

The term *pitch* is used to designate the descent or inclination of the ore-bed or *shoots* of ore towards the northeast—or in the line of strike. If we should conceive of the line of strike as broken and depressed so as to descend towards the northeast, we should get a good example of this *pitch* of *shoots*. This inclination has been observed in the rock as well as in the ore. It is so commonly observed in mining these magnetic ores as to be expected everywhere, and min-

ers speak of the ore *pitching* or *shooting*, and their working has constant reference to such a structure in both ore and the inclosing rocks. In nearly all cases the pitch is towards the northeast. It is beautifully exhibited in the Cannon mine, at Ringwood, where it amounts to 45° inclination from a horizontal line. The long slope of the Hurd mine, in Morris County, and the thick swells alternating with intervening *pinches*, or barren ground, at Mount Hope, show this same structural phenomenon.

These *shoots* of ore, however named, are best described as "irregular, lenticular masses of ore imbedded in the gneiss, their longest diameters coinciding with the strike and pitch of the rock," which in nearly all cases is towards the northeast, and their dip conforming to that of the same surrounding rocky *case*, and generally at a high angle towards the southeast. They vary greatly in their dimensions, sometimes thinning out or *pinching*, when followed on the line of the strike, or on that of the dip, to a thin sheet or seam of ore and occasionally ending wedge-like in rock. Sometimes they split up into several small veins or *fingers* which are dovetailed, as it were, in with the rock, and so gradually pinch out. Quite often there is a sort of flattened kernel or core of rock inclosed in the shoots of ore, but generally these *horses*, or what are called such, are interpenetrating masses of rock from the outside *country rock*. Extensive mining operations and explorations have shown some of these shoots to be connected with others, forming a series of these lenticular masses, or if not actually united by ore, associated and arranged on closely parallel planes, if not in the same axial plane. Following the plane of the dip downwards, the *pinches* between the shoots are nearly everywhere continuous sheets of ore, and these are not often greater in breadth than the shoots. That is, the distance from shoot to shoot measured across the pinch is not often greater than the breadth of the former. But quite frequently these shoots are entirely separate from one another, rock intervening in the same plane, or they are in different planes or geological horizons. Nearly all of our New Jersey mines work on more than one shoot, since the extraction of the ore from near the surface is easier and more economical than following a single shoot downwards. Their length is unknown. In the Hurd mine the slope is nearly 900 feet long descending on the *bottom rock* and there are no signs of exhaustion. In the Weldon mine (near the Hurd mine) there are two shoots side by side, but not exactly parallel, nearing each other as they pitch down, and now separated by about twelve feet of gneiss rock. These may come together and prove to be leaders from one large shoot.

In most of our iron mines the ore is bounded by well defined walls or strata of rock from which the ore comes off *clean* in mining, but very frequently there are no such plain boundaries or sudden transitions from magnetite to gneiss, but a very gentle gradation of ore into rock, and in these cases the mining goes only so far as the richness of the beds in iron makes it profitable to remove them. Following the *shoots* downward, the same gradual replacement has been observed until the whole was too lean to work, or altogether free from ore; but this feature is not so common as that of the gradation or replacement towards the sides of the shoots or the walls. Occasionally the shoot is said to run out, that is, there is a sudden change from ore to rock; some of these, however, may be faults rather than shoots changed in mineral composition.

The thinning out of the shoots towards the edges, or at right angles to the line of pitch, or towards what may be called the *lines of pinch*, which run parallel to the lines of *swell* or axes of these shoots, has originated the terms cap-rock and bottom rock. The former makes the arched or double-pitched roof of the mine, while the latter constitutes the trough-like floor or bottom. These peculiar features are very finely exhibited in the Hurd mine, Hurdtown, Morris County, where the extraction of the ore, following the conformation of the shoot, has left the *cap-rock* overhead and the *bottom rock* below, on which the long slope runs down to the bottom of the mine.

In the Cannon mine, at Ringwood, the same capping rock appears in the heading or northeast side of the large opening, and the track runs down on the bottom rock towards the northeast.

Here the pitch is nearly twice as great as in the Hurd mine and the shoot as worked is much broader being nearly of the same size both ways. And here there may be said to be *four* walls that surround the ore. Sometimes miners speak of these top and bottom rocks as walls. But generally there is a narrow vein or sheet of ore left both at the top and in the bottom; and these may gradually run out entirely, or they may connect with other shoots of ore lying in the same plane of dip as that of the shoot worked. And this is true in nearly every case; the exceptions being considered as not yet fully demonstrated as such, since the mining operations generally cease when the vein pinches up so as to become unprofitable for the removal of its ore.

The extent of these *shoots* of ore is exceedingly varying, and our mines are not yet deep enough to show their maximum length. The width and thickness, or the lateral dimensions, are soon ascertained, the former scarcely ever exceeding one hundred feet, from *cap* to *bottom rock*, or from *pinch* to *pinch*; and the latter varying from an inch to eighty feet; but more often less than thirty feet—they may average five to twenty feet. These figures always include some rock, or *horses*. The oldest and deepest of our mines, as the Blue mine, at Ringwood, the Mount Hope, Swedes, Dickerson, and Hurd mines, are all steadily going down, increasing the length of their slopes, and they are apparently as inexhaustible as ever, and promise to continue so, at least as far as our present appliances for hoisting ore and water can allow of the economical extraction of ore from them. Such are some of the more general and essential features that characterize the iron-ore beds of the State.

Lying imbedded in, and being contemporaneous in origin with, the gneissoid rocks of this Azoic formation, these ore beds or *veins* have been subject to the same disturbing forces which have elevated, folded, wrinkled, and broken all the strata belonging to it, and which have given to it its present structure. These forces, so manifold and acting through so long a period of time, and probably at wide intervals, have so destroyed any degree of uniformity which once may have existed, that it is often difficult, and sometimes impossible, to recognize amidst this chaos any order of structure whatever. The beds of ore and rock have been squeezed into close folds, so that they now stand on edge, and through these agencies have come the strike and dip. Other forces acting on lines traversing the veins at all angles, have variously dislocated and further disturbed the strata, giving rise to frequent *faults* or *offsets*, and what are called *cross-slides*—phenomena seen in both the veins and in the rock strata of this formation. In some instances the veins have been displaced one hundred feet, while in others the ore-mass has been broken apart, but not pushed aside, so as to interrupt its course. The planes of these dislocations traversing the veins in all directions, the dip and strike are sometimes both altered. These faults are common, and can be seen in nearly all of the mines; sometimes so frequent as to cut the vein into short segments, giving it a zigzag course. The most remarkable faults or offsets are seen in the Mount Hope mines, where five veins are all displaced over a hundred feet; in the Hurd mine, where the displacement has been in a vertical plane and the original long and continuous shoot appears as two distinct masses, the upper of which has been worked out. Other examples are in the Byram and the Mount Pleasant mines, near Dover. Generally a thin seam of ore mixed with rock connects the vein on corresponding sides of the fault, and this serves often as a guide to find the vein beyond the break or offset. Miners have several so-called rules about offsets, but these are not universal, and there is no general law in the direction of the throw or displacement. Occasionally one fault is crossed by another—increasing the irregularity in the course of the vein.

From these numerous faultings, discovered in mining operations, we learn something of the extent to which these strata have been disturbed since their original deposition, and probably all subsequent to their elevation and compression into folds. More thorough surveys of the surface and more extended mining may yet enable the geologist and miner to trace out these lines of fracture, and learn how much they, together

with the general effects of elevation and folding of the whole formation, have contributed towards the grouping of the iron-ore as we find it, and this knowledge may direct both our mining and our searches for ore. The facts already obtained point to a system, and the successful pursuit of the ore in its crooked and broken course in some of the largest mines is the best evidence of the accuracy of the laws of structure as now understood.

They also show most forcibly, and illustrate most beautifully, the intimate and necessary relations of mining and the principles of geology, and show that the two ought never to be dissociated.

VENTILATION BY VERTICAL SHAFTS.

From "The Architect."

THE *Times* has published a long article upon a discovery by a Mr. Tobin, of Leeds, of a method of ventilation which, it is affirmed, renders the atmosphere of any chamber as pure as that outside the building, without improper lowering of temperature, and without the production of draught. Mr. Tobin's own account of the matter is that he was once watching a current of water which flowed into a still pond. He observed that the moving water kept together, and held its own, until its course was arrested by the opposite bank, when it curved gently round on either side, and was lost insensibly in the general body, which had its outlet for overflow at one side. He reflected that a current of air introduced into a room would act precisely in the same manner, keeping together until it encountered an obstacle, then mixing insensibly with the air around it, and compelling an overflow wherever there was an opening available. He saw that, if this were so, it would only be necessary to give the entering current an ascending direction, so that it would reach the ceiling without impinging on any person, in order to solve the whole problem of domestic ventilation. Experiments at his own house confirmed his anticipation, and led him to contrive methods, which he has patented, of carrying his principle into practice.

At that time the state of the Borough Police Court at Leeds was, as, indeed, it had been for some time previously, a source of great perplexity to the Town Council. The Justices were often compelled to make their escape before the business of the day was concluded; and the Council had expended between £1,400 and £1,500 on successive ventilation doctors, each of whom had left matters as bad as, if not worse than, they were before.

Mr. Tobin suggested that the Council should pay him a nominal royalty for the use of his patent, and that they should pay the few pounds required for doing the work, leaving his own remuneration to their discretion when they saw the effect. These terms having been accepted, he placed under the floor of the Court three horizontal shafts which communicated with the open air through a cellar grating. From these were brought eight vertical shafts through the floor at different points. The shafts rise about four feet above the floor, and are each five inches in diameter. They have open mouths, and are placed out of the way in corners, or against the partitions of the Court. From each shaft there ascends to the ceiling an unbroken current of the outer air, like a fountain, or like a column of smoke when the barometer is high. The current will support feathers, or wool, and other light substances, and has so little tendency to spread laterally that it can be made to influence half the flame of a candle, while the other half remains undisturbed. A person resting his cheek against the margin of one of the tubes feels no draught, and the hand feels none until it is inclined over the orifice. The effect was instantly to render the Court as fresh and sweet as the external air of the building, as the products of respiration was forced out through the skylight.

After three months' trial, and after all

the magistrates for the borough had joined in a report, which expressed their entire and unmixed satisfaction, the Corporation voted Mr. Tobin an honorarium of £250, to express their sense of the benefit which he had conferred upon the town. They also applied his system to the Council Chamber; and their example was followed by some of the leading bankers and merchants, by the churchwardens of St. George's Church, and by the proprietors of the *Leeds Mercury*.

The system of vertical tubes is necessary for rooms which have no side windows, or which have only a small window surface in proportion to their cubic contents. But Mr. Tobin at the same time contrived a cheap and simple method, by which vertically ascending air currents can be introduced through common window sashes; and this method will suffice for all ordinary living or sleeping apartments. Each of the openings made for this purpose is provided with a cover by which it can be closed at will; and they admit of a method of securing the sashes which affords almost entire security against burglars. A very competent authority has communicated to the *Times* his experience for eight weeks of a room containing 2,500 cubic feet, ventilated, under Mr. Tobin's direction, by four window openings which have an aggregate area of 30 square inches, but which are filled by layers of cotton wool to filter the entering air from dirt and moisture. The currents ascend in absolute contact with the glass, keeping so close to it that they do not not affect the flame of a taper which is held vertically in contact with the sash bar; although, as soon as the taper is inclined towards the pane its flame is strongly fluttered. In this way the air ascends to the top of the window, where it is directed to the ceiling and lost as a current, being no longer traceable by taper, hand, or fragments of down, although closing the window openings diminishes in a marked manner the draught up the chimney. Each opening, as already described, has an independent cover, and, without the wool, the four would, in cold weather, be too much for a room of the size specified. With the wool they do not perceptibly diminish the temperature, but they give a feeling of absolute out-of-door freshness, which must be experienced in order to be appreciated. There is no draught anywhere, and the openings are not visible unless sought for, so that curious inquirers who have remarked on the result have been unable to find the inlets. Arranged as described, the openings are sufficient to feed a large argand table gas burner, and to sweep away entirely the products of its combustion; so that, when the room is shut up, with the gas lighted and with a good fire, for three or four hours, persons entering it from the open air are not able to discover, except by the greater warmth, any change of atmosphere. A bed-room ventilated in a similar manner is as fresh when the door is opened in the morning as when it was closed at night.

Mr. Tobin's experiments early led him to the conclusion that the prevailing notions about the necessity for carefully planned outlets were fallacious, and that, if proper inlets are provided, the outlets may generally be left to take care of themselves. In order to test this, he fitted two vertical tubes into a small room which had a fire-place and a three-light gas pendant. He closed the opening of the fire-place, and every other opening into the room, except the tubes, hermetically, and shutting himself within, pasted slips of paper all round the door. He found that there was then no entrance current by the tubes. The room had no outlet; it was full of air, which his respiration had not had time to consume in any appreciable quantity, and no more could get in. He next lighted the three gas burners, and a steady entrance current immediately set in through the tubes, and continued as long as the gas was burning. He waited nearly an hour without any deterioration of the atmosphere becoming perceptible to his senses, and with the currents steadily coming in and ascending in their customary manner. He then cut through the paper which secured the door, and left the room, shutting the door behind him. Returning half an hour later, he found the atmosphere still fresh. He next extinguished the gas, and the currents gradually died away, the original state of equilibrium or fulness being restored. This experiment, which has been several times repeated, seems to show that the external air will enter just in proportion as room is made for it by

combustion or respiration, and that the rate of supply is essentially governed by the rate of destruction or demand.

In order to obtain an absolutely perfect result it is necessary to bear in mind that the behavior of the entering current will be precisely like that of the vertical column of water sent up by a fountain, except that, as the ascending air is received in a fluid of only little less density than its own, it will mingle with that fluid gradually when the propulsive force is exhausted, instead of falling almost vertically by the action of gravity. But just as a fountain, if it encountered an obstacle while its column was still compact, would rebound from that obstacle with considerable violence, so the entering current of air, if it meet with an impediment prematurely, will be reflected as a draught. To prevent such an occurrence, it is necesssary to make the inlets so low down that, under all ordinary circumstances, the force of the stream will be expended before the ceiling is reached; and when, from any circumstances, this cannot be done, the current may be broken by strainers of wire gauze or other suitable material. In this, as in most other matters, some special adaptation of means to ends is required; and the arrangements for any given room must be planned by some one who has practical knowledge of the subject.

Within the last two or three weeks Mr. Tobin has adapted his system to the Liverpool Police Court, and there, as well as at Leeds, he has entirely succeeded in attaining his object, and the satisfaction given to the local authorities has been such that it has been determined that all the other courts in the Town-hall shall at once be ventilated in a similar manner. In London the method of ventilation by vertical tubes has been applied to one of the wards of St. George's Hospital, and that by window openings to the Council Chamber of the Society of Arts and to a few private houses, everywhere with the same excellent results.

The discovery that the pressure of the atmosphere can thus be utilized as a perpetual source of air supply, without the aid of fans or other mechanical contrivances; the discovery that all draughts can be obviated by the employment of vertical entrance channels, provided only that their mouths are not too near the ceiling, and the discovery that improper lowering of temperature is prevented by the circumstance that the rate of entrance of air is governed by the demand, are truly comparable in their simplicity to the balancing of the egg by Columbus. Simple as they are, they are none the less calculated to add greatly to the public health and comfort.

Captain Douglas Galton, commenting on the invention, says:—The principle of ventilation by utilizing the pressure of the atmosphere is not new. It has been applied in a number of ways in various public and private buildings; notably in the method of barrack ventilation adopted in 1857 by the Barrack and Hospital Commission under Lord Herbert's auspices. Nor is there any novelty in the method of introducing fresh air into a room by means of vertical shafts delivering the air into the room at a few feet from the ground. I used it in 1861 in the wards of the Herbert Hospital at Woolwich, and in other hospitals, but I utilized the fire-place for the purpose, placing it in the centre of the ward, with its flue carried under the floor, in order that in cold weather the fresh air should be tempered by the spare heat from the fire. Plenty of other instances might be cited.

The principles of ventilation are well known. It is the application of those principles in special cases which causes the difficulty. The amount of current of inflowing air into a room will depend upon the facilities or arrangements for outflow, and *vice versa*. Therefore, for perfect ventilation, the proportions and position of both outlet and inlet must be considered; neither can be neglected; and if in the room on which Mr. Tobin experimented the air remained pure, it was because there was, in addition to the inflow, some means for an outflow of a sufficient quantity of air to remove the impurities given out from the lungs in breathing and from the gas in combustion. In English rooms of ordinary construction the open fireplace creates the difficulty in the introduction of fresh air. It is the cause of draughts, because the chimney with a fire in the grate is a strong engine for removing the air from a room, and it draws in through every

means of ingress air to supply the place of that removed. If this air comes in cold draughts are felt, whatever be the position or manner in which the air is delivered. The hotter the fire the stronger the current up the chimney, and the greater the draught. For this reason, if a room with an open fire is to be really comfortable it should be provided with a continuous supply of fresh warmed air, and if the inlet be from 6 to 9 feet above the floor the inflow will not be felt by the occupants. The waste heat from the fire affords the most economical method of warming the fresh air.

When the principles of ventilation, which are perfecly well known, are carefully attended to, and where the inlets for fresh air and the outlets are duly proportioned to each other and placed in proper positions, and the fresh air adequately warmed and cooled as required, there will be no failure in ventilation. Where failure does occur it is either because of a misapplication of principles, or of a disinclination to incur the necessary expense for carrying the principles into effect.

THE STABILITY OF ARCHES.

By E. SHERMAN GOULD, C. E.

Written for VAN NOSTRAND'S MAGAZINE.

It is customary, in discussing the conditions of stability of an arch, to consider the arch-ring as sustaining, besides its own weight, that of the entire superstructure raised over it, and receiving at the key-stone the whole horizontal thrust of the combined mass.

That this view is an erroneous one, is clearly evidenced by the perfect stability of many light arches standing under high spandril walls ; a stability which could never exist were the actual conditions of pressure such as would be commonly assumed in calculating the proper dimensions for the arch-ring.

Such a pressure from the surcharge is only found in the case of a liquid mass, and then the direction of the pressure upon each voussoir is toward the centre of the arch, and not vertically downward as in the case of a coherent mass, bonded in with the extrados of the arch-ring.

Suppose, in the case of a spandril wall, such as is shown in half elevation in Fig. 1, that the arch-ring were removed. What would be the result? If the common assumption were true, the entire wall within the span, would fall bodily to the ground. Now we know that this would not really occur, but that an irregular mass A, varying in size according to the span and character of the wall, would detach itself and come down, not probably in a body, but by piecemeal.

In general terms, we may say that the office of the arch-ring is to sustain that

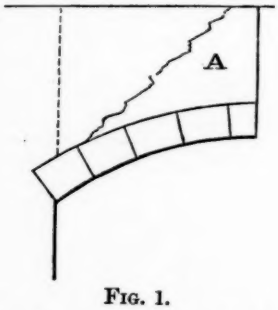


FIG. 1.

portion of the surcharge which is not self supporting. Moreover, the arch and wall thus sustained, form together an arched girder, and the horizontal thrust of the combined mass is resisted by the entire section from the soffit to the top of the wall. So that, in point of fact the higher the wall the greater the safety to the arch-ring. Indeed, one would feel instinctively, that he could knock a hole through the foot of a high brick wall with greater impunity than through a low one, particularly if there were a heavy surcharge resting on the top.

In this connection I may be pardoned for offering what I consider a much sim-

plified method of determining the line of pressure in an arch-ring. The plan, introduced by Mons. Méry, and I believe at present almost universally adapted, at least in principle, is to ascertain the weight of arch including surcharge, ascertain its centre of gravity, derive the horizontal thrust, apply this latter to some point in the vertical section of the crown, and, combining it with the weight of successive portions of the arch, work the resultant down to skew-back. The consideration of certain facts in relation to a loaded arch lead us, I think, to a preferable method of procedure. Whatever may be the conditions of loading, and whatever direction the line of pressure may consequently follow, we know that each abutment must sustain one half of the weight of the arch and load, and that this weight on the abutment must have a resultant at right angles to the skew-back. We have then here a positive basis to start from, and by combining this resultant with the weights of the successive voussoirs and their respective loads, we can trace the path of the line of pressure through the arch-ring.

Thus, suppose Fig. 2 to represent an arch, 60 feet in span, with a rise of 15

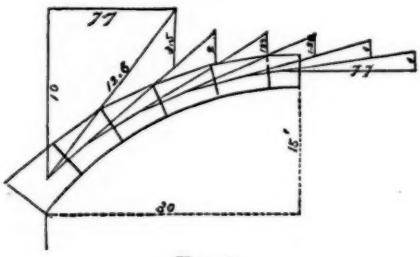


FIG. 2.

feet, the intrados being the arc of a circle, struck with a radius of 37.5 feet. Let us suppose the weight of voussoirs and corresponding loads, commencing next to the skew-back, to be represented by the numbers 3.5; 2; 1.25; 1.25; 1 and 1 respectively. This gives a weight, represented by 10, resting on the abutment. The reaction of this weight, acting vertically upward, and the horizontal thrust, have a resultant, as we have seen, named to the skew-back, represented by 12.6, the horizontal thrust being represented by 7.7. Transferring this triangle of forces to the centre of gravity of the first voussoir, and combining the weights in and on each voussoir successively, we carry the line of pressure through the arch-ring, and recover the horizontal thrust of 7.7 in the resultant at the crown. (This procedure will somewhat remind the railroad engineer of the method of locating a curve by chord deflections.) The shorter the voussoirs, the nearer the differential will approach to the arcs, the nearer the broken line will approach to a true curve, and the nearer will the first centre of gravity approach to the skew-back, and the last to the mid section of the crown.

This process demonstrates itself, and is moreover merely an application of the well-known principle of the suspended chain, but it will be satisfactory to apply it to some known curve of equilibrium, and see how they agree. Of all external pressures which we encounter in construction, hydrostatic pressure is the one about the action and direction of which we are most certain, and therefore, of all curves of equilibrium, the hydrostatic curve is the least ambiguous. Let us take the example of this curve, given by Professor Allan, page 387 of the tenth volume of this Magazine. With a span of 50 feet and a depth of load at the crown of 16 feet, the Professor gives as the radii, at crown and springing, of 32.5 feet and 14.1 feet respectively. He also gives as the formula $S=\frac{y_0 p_0}{y}$ for the radius at any point, situated at a depth y below the water line. The curve is now to be found by approximation. Start at the crown with the radius 32.5 and strike a short arc. From the end

away from the crown, measure the vertical distance y to the water line, and dividing the constant $y_0 p_0 = 5.20$ by this distance you obtain the next radius. Proceed thus to the end of the arch, when you will find that you have overrun the span by a distance less or more, according as the divisions have been more or less numerous. Now, begin at the springing, with the radius 14.1 feet, and work back toward the crown. You will find this new curve gradually approach the first one for a certain distance, and then begin to leave it. Stop here. You have now two curves, between which the true curve lies, and with one of which it coincides at the crown and springing. The margin will be less, the greater the number of small arcs you have taken. Sketch the true curve in by hand, and selecting, by trial, a few centres, strike in a clean curve coinciding with the hand-made one. It will be well to test these centres, and the corresponding radii, by the formula $p = y_0 p_0$, measuring p and y on the y drawing. Now (Fig. 3), take the area a, b, c, d, say in square feet, which will

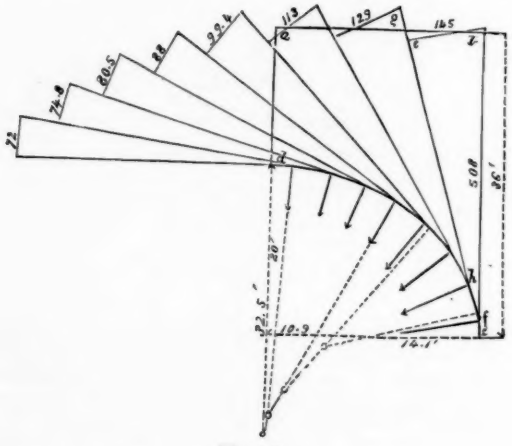


FIG. 3.

represent the weight resting on each abutment for a foot's length of arch. We have for this, the number 508. Then divide the curve into a certain number of equal parts, 8 in the figure, and multiply their common length by the distance from their centres of gravity to the water line. This gives the pressure on each of the equal arcs in terms of the weight on abutment, which pressure is directed toward the centre of the circle of the same radius as the arc. Draw lines from the centre of the arcs, properly directed, and make them of a length representing by scale the amount of pressure on the arcs to which they belong. Then, from the first centre of gravity, next the springing, draw the vertical 508, and from its upper extremity draw a line, parallel to the direction of the pressure on that centre of gravity, and equal, by scale, to its amount. This gives us the triangle of forces, b, e, f. Produce f, e, making h, g, equal to f, e, and proceed thus through to the crown. It will be found that the curve thus obtained coincides with the hydrostatic curve located by the formula, and the resultants equal $T = H = V$, as they should.

No account has been here taken of the weight of the voussoirs, which, as they act vertically, would somewhat modify the curve

In closing, I may add that I do not recollect seeing in any work in English, Dejardin's excellent and simple method of tracing the extrados of an arch in equilibrium, when the intrados is given. It is shown, in its most simple applica-

tion in Fig. 4, which represents part of an arch with arc intrados following a

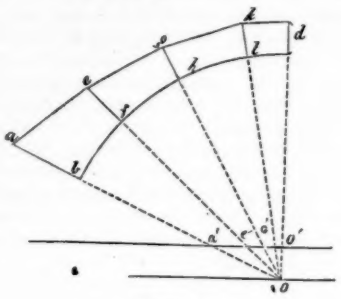


FIG. 4.

circular arc. The method is based on the principle, that, as the horizontal thrust is constant throughout the arch, the vertical projection of each joint $a\,b$, $e\,f$, etc., should be equal to the depth d, at the crown. This is secured by drawing a horizontal line at a distance $0\,0' = d$ above the centre of the circle to which the intrados is struck, and making the distances $a\,a'$, $e\,e'$, etc, on the radii produced, = radius.

This method is general. In the case of an intrados struck from several centres (Fig. 5), let

r = radius at the crown.

r' = radius at any joint, making an angle d with the vertical.

e = depth of arch-ring at crown.

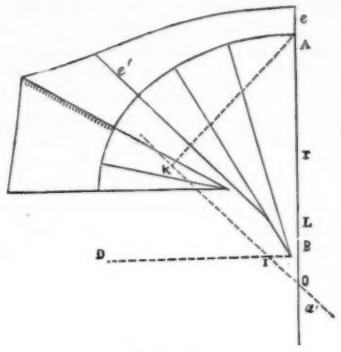


FIG. 5.

Then, $e' = \frac{r}{r'} \times \frac{e}{Cos.\ d}$, sufficiently near in practice.

On the vertical $O\,A = r$, take $O\,B = e$, and draw the horizontal line B D. To obtain the length e' of a joint making an angle d with the vertical, through O, draw O K parallel to the joint e', and $= r'$. Through the point I, where O K meets B D, draw I L parallel to A K. Then O L will be the length e' required. For, A O K, L O I being similar tringles,

$$O\,L = \frac{O\,A \times O\,I}{O\,K} = \frac{r}{r'} \times \frac{e}{Cos.\ d}.$$

TESTS OF STEEL.*

BY A. L. HOLLEY, C. E.

THE intention of this paper is not to discuss this important subject in all its bearings, but merely to point out why mechanical tests of steel, as ordinarily made, are not, *alone*, of any special value to engineers—certainly not to general mechanical engineers.

The agents of the Barrow Hæmatite Steel Company, one of the largest and most successful Bessemer establishments in England, have recently distributed a report, made by Sir William Fairbairn, on the transverse, tensile and compressive resistances of certain bars of this steel. The number of tests is very large; they seem to be careful and minute; and the modulus of elasticity, the work up to the limit of elasticity, and the limit of working strength, are fully tabulated according to the latest formula.

This is very well—indeed it is indispensable, as far as it goes; but it goes no further than to inform the ordinary engineer that there is an unknown substance which possesses these physical properties. As to *what* the substance is, the report gives him no working knowledge, for not a single analysis is given of any of the bars tested. The most

* A paper read before the American Institute of Mining Engineers.

that is said of some of them is that they are either "hard" or "soft," which is sufficiently evident from the experiments. "A bar of steel" is, in the present state of the art, a vastly less definite expression than "a piece of chalk." To the engineer who wants steel for a specific purpose, it gives only the faintest clue, to say that steel is hard or soft. There are a dozen grades of both hard and soft steel, adapted to different purposes. Rail steel is soft, and boiler-plate steel is soft, as compared with many structural steels, and with the whole range of spring and tool steels; but the one perfectly adapted to rails would be useless for boilers.

In order that engineers may know what to specify, and that manufacturers may know not only what to make, but how to compound and temper it, the leading ingredients of each grade of steel must be known. Pure iron would be unfit for nearly all structural purposes. Upon the substances associated with it depend its hardness, malleability, stiffness, toughness, elasticity, tempering qualities, and adaptations to various structural uses. These ingredients are indeed impurities, but the *term* "impurity" unfortunately implies a defect, whereas the *thing* may really impart the essential quality. All the usual ingredients give what is called "body" to steel. Carbon, within specific limits, as is well known, gives hardness, elasticity, resistance to statical strains, and tempering qualities. Under certain conditions of composition it even gives resistance to sudden strains. Manganese (and this fact, by the way, is not so generally known) gives, in the proportion of ¾ to 1 per cent., hardness, toughness, malleability, and elasticity. Chromium imparts similar qualities, but to what precise extent we do not know, in default of a proper comparison of chemical and mechanical tests. Silicon, although considered a bane by steel-makers generally, and, singularly enough, advertised as the great panacea for the weaknesses of steel by certain modern inventors, has probably, in proper proportions, a healthful influence on the physical properties of steel. Even phosphorus, the arch-enemy of the Bessemer and open-hearth manufacturers, may in some degree be a valuable ingredient.

Whether or not certain foreign substances, which separately added, produce similar results, would produce a better result if combined in certain proportions—for instance, whether carbon alone in any degree, or silicon alone in any degree, would make as good a steel for certain uses as carbon and silicon combined, it is, in default of proper experiments, impossible to state. The probability is, that there is a proportion of carbon and manganese which would give the highest possible value to all structural steels. We formerly added spiegeleisen to decarburized Bessemer metal solely to impart manganese to the oxygen of the oxyde of iron formed in the Bessemer process. We now add a larger proportion of spiegeleisen, not only to remove the oxygen, but also to mix manganese with the steel. And we think we find that if the proportions of silicon and phosphorus are sufficiently low, and carbon does not exceed a third of one per cent., manganese to the amount of three-quarters per cent. to one per cent. gives the resulting product a high degree of toughness and hardness combined—a degree of suitableness for rails, which no proportion of either carbon or manganese, not associated, can impart.

When we consider that two and three-tenths of one per cent., and in some cases a fraction of a tenth of one per cent. of foreign metals, will change the character of steel in a high degree; and when we farther consider that the physical results of these combinations have never been tested or analyzed in any thorough and comprehensive manner, we may well reiterate the common expression, that the iron and steel manufacture is in its infancy.

But it is not necessarily in its infancy. We simply do not develop it. The general complaint of engineers and machinists is, that they occasionally get, but can never get regularly, the precise quality of steel they require; and yet it is probable that thousands of tons of steel have been made which are suitable for each of these purposes, but have been used for others, and that the precise grade required in every case could be reproduced by the ten thousand tons. The trouble is that neither the user nor the maker knows what the material *is*.

They have put no mark on it by which they can recognize it; they have kept no recipe. All they can do is to use ingredients of the same name, and approximately the same quality, and to guess at the physical properties of the product, aided by such crude tests as can be made during manufacture. Mr. William H. Barlow, in a late address on modern steel before the British Association, says that one reason why steel is not more used for structural purposes is, that the metal is of various qualities, "and we do not possess the means, without elaborate testing, of knowing whether the article presented to us is of the required quality." But neither Mr. Barlow, nor any of his associates in government experiments, proposes the true solution of the difficulty. It is no more necessary to test one or two of each lot of bars to destruction, in order to find out the quality of the rest, than it is to burn up a Chinese village to get roast pig.

If the user would *analyze* not one, but twenty samples of the steel that meets a particular want, and then base his order on an analysis that should come within the highest and lowest limits of the samples, he would get substantially the same metal every time. The problem is a more difficult one for the steel-maker, since he must analyze the many materials that go into his product; but if he imposes the same restrictions on the makers of these materials—in short, if from the ore and limestone and coal, up to the finished bar, each user buys by analysis, and pays in proportion to uniformity, the production of steel of the most multiform grades and qualities, each homogeneous and uniform to any extent of production, becomes a possible, if not a comparatively easy, matter.

What are Sir William Fairbairn, and Mr. Barlow, and Mr. Kirkaldy, and the other great experimenters in the physical properties of steel—in its adaptation to certain specific uses—what are they doing to relieve the engineering world from these uncertainties? They are simply discovering the vast number of qualities which steel may be made to possess, without giving more than a clue to the method by which these qualities may be predetermined and reproduced. They are going to a vast expense of time and material to inform us, not that a certain combination of metals, but that "a *bar of steel*, has such resistance and elasticity. This sort of experimenting has much the same value as the steam-engine tests of a late chief engineer in the navy, of whom it is said, that in a coal-consumption test he would calculate the ashes to ten places of decimals, and guess at the coal put into the furnaces.

Moreover, Sir William Fairbairn may be doing injustice to other steel-makers, to Brown, Cammell, and Bessemer, bars of whose steel he has also similarly tested, and found not quite so suitable for certain purposes as the Barrow bars are. But he neglects to make it clear that the disparaged bars may be better than these particular Barrow bars for other purposes. He makes the mistake which we should suppose Sir William, of all men, would not make, of being absurdly general and random in one element of his conclusions, while he is fractionally accurate in others—of cramming the whole matter of chemical ingredients into the terms "hard" and "soft."

The first and easiest step in the desired direction is to find out what *X* is. It is not necessarily a bar of steel made by Turton & Sons, which one tool-maker will swear by, and another will swear at; nor is it necessarily a boiler-plate steel which Park Bros. made once, and Firth got at twice, and Singer, Nimick, & Co. hit two or three times. It is a steel which Turton, and Firth, and Park, and Singer, can, either of them, make by the ten thousand tons, if you will only tell them what it is made of, as well as what its physical qualities are. In the various uses to which engineers have applied steel, there are a vast number of specimens which have long fulfilled all the requirements. When more steel of the same sort is wanted, the usual method is either to apply to the same maker, who kept no complete record, and does not know what is wanted; or to get bids based on a stereotyped and very inadequate physical test, for instance, that the bar must stand such and such a blow from a drop. The lot of steel is made, and is, as well it may be, very heterogeneous in physical character, although it may be in accordance with the one test. The result is that, under wear, some of it fails, or, under load, an excessive margin

of safety must be allowed. The obviously rational way to reproduce a lot of steel which is proved suitable for any purpose, is to analyze many samples of it—at least for carbon, manganese, silicon, phosphorus, and any element which exceeds a tenth of one per cent., and thus to give the steel-maker a recipe for making it.

It may be suggested that this chemical synthesis of steel will be ruinously costly. For certain exact purposes, such as the members of a long-span bridge; or for certain fine purposes, such as gun-barrels, the cost of analyses, or any loss in applying to other uses the lots of steel that were not up to the mark, would be very small compared with the extraordinary margin of strength that must be given to an uncertain metal, and compared with the cost of occasional failures under final test. And this cost, whatever it is, the user—that is to say, the public, snould and must bear.

But steel-makers will find that working by analysis is not so very formidable after all. The color-test of carbon is already applied to all charges of all Bessemer and open-hearth makers, and it is one of the most important. There is another view of the case. After a certain experience in comparing mechanical tests, which are comparatively easily made, with the more costly determinations of manganese, phosphorus, etc., the expert will not need to analyze every charge. He will learn to read manganese, approximately, in an elastic limit test, just as the expert blacksmith can now read carbon quite accurately by the water-hardening test. Herein will lie one of the values of the combined mechanical and chemical tests, that they will supplement and prove each other.

When the proper amounts of carbon, manganese, silicon, etc., for certain uses are known, it will not be impossible to approximate to them, in the Bessemer process, to a very helpful degree, and in the open-hearth and crucible process, to a reasonably accurate degree. Of course, the character of the ingredients must be much more definitely known than at present, and numerous batches of nominally the same ingredient, such as pig-iron, blooms, or puddle-balls, must be mixed, so as to largely dilute any high degree of impurity which any one batch may contain.

The thing first in order is, of course, to ascertain the mechanical properties of all grades of steel—not merely the individual resistances to destructive strains, which are but the stones that compose the mosaic, but the resistance within the elastic limit, which is the finished picture. To this end experiments like those of Sir William Fairbairn are indispensable, but to these must be added analyses of every grade of steel that can be produced, or the character of the metal is but half known.

In the present state of constructive and metallurgical art, it thus seems not only vitally important, but highly feasible, to increase in a large degree the uniformity of all grades of steel, and to make grades adapted to all special uses, instead of following the hit-or-miss and large-margin system, or want of system, that now obtains. Of course, the change must come slowly, and its early stages will be attended with difficulty and expense; but there can be no question as to its ultimate success and its immense advantage in constructive and manufacturing engineering and art.

What probable expense of experimenting is to be considered when it will increase, possibly double, the resistance of metals to specific stresses, and decrease the present enormous margin of safety? It seems unaccountable that government commissioners have so long neglected the chemical half of the problem—have so long neglected to complete the circuit, so that the metal will tell us its own story.

NEW METHOD OF DEVELOPING MAGNETISM.—Tommasi has recently stated in a paper communicated to the French Academy of Sciences, that when a current of steam under a pressure of five or six atmospheres is driven through a copper tube one-eighth to one-quarter of an inch in diameter, wound in the form of a helix, a bar of iron placed in the axis of this helix, becomes so strongly magnetized that a needle placed several centimetres distant from this *steam-magnet*, is decidedly attracted. The magnetism remains in the bar so long as the current of steam continues.

WATER SUPPLY AND DRAINAGE.*

By W. A. CORFIELD, Esq., M.A., M.D.

II.

COLLECTION AND DISTRIBUTION OF WATER.

Having found a sufficient supply of good water, or a sufficient supply of water that can be purified on a large scale by filtration—a subject which we shall consider further on—or by means of Clarks' process, which I have described to you, or by both combined, we come to the modes of collection and distribution, which vary very much as to the site, sources, &c. One of the oldest plans, and for all that one of the best, is the eastern or Roman plan, if you like so to call it, which is that of tapping natural springs at their sources, or lakes, above the places to be supplied, and conducting the water by channels or aqueducts above or below ground, or alternately above and below, as occasion may require; collecting it in large cisterns, allowing the sediment to settle, and then distributing by means of gravitation.

In later times we can adopt the same plan, and distribute either by gravitation or by steam power as we choose. Permanent springs at a distance may be conveyed by the Roman plan through channels across the country, covered the whole way right up to the distributing reservoirs or tanks. The conduits may be built of masonry and cement, like the Roman aqueducts, embedded in puddle, or they may be earthenware pipes, in which case they must be laid in watertight trenches, and jointed securely, or the water may be contaminated in various ways, and much of it may be lost, or the pipes may be of cast-iron, and this should be the case where deep valleys have to be crossed by means of inverted syphons.

Earthenware pipes are not strong enough to be used as inverted syphons. The rule is, that if the fall is greater than 1 in 300, then cast-iron pipes should be used. The fall of these conduits should be 5 feet in a mile, if they are of something like 2 feet in diameter, which is of a small size. If larger, it may be less, down to 1 in 10,000, or 6 inches in the mile. That is the fall of the New River conduit that supplies part of the north of London with water.

The velocity of the water should not be less than one foot in the second, so that it may move at a sufficient rate, nor greater than four feet in a second, for fear it should wear away the course by carrying down stones, etc. As an opinion about this plan, which I am going to describe to you at greater length, I may mention that Mr. Rawlinson stated, in a discussion on the water supply of Melbourne, which you will find reported in Vol. 18 of the proceedings of the Institution of Civil Engineers, that "he thought the plan of gathering spring water in Great Britain, by means of earthenware pipes to some common storage reservoir, was one that might be favorably looked at; the modern means of making earthenware pipes offered many facilities; and where springs were at a sufficient elevation and tolerably permanent, the water might be collected and brought into a covered reservoir on the Eastern plan. There were situations where that plan might be preferable to making an impounding reservoir."

Now, I should like to give you a short account of some of the points which are to be observed in the Roman aqueducts at Rome; and afterwards I propose to give you an account of some extremely remarkable Roman aqueducts which are very little known, and which have been very seldom described, to wit, the aqueducts with which the town of Lugudunum, now called Lyons, was supplied, which aqueducts have some very interesting and instructive points about them, as you will see directly.

As I think I told you before, Rome was supplied by nine aqueducts. The first two were built entirely underground for their whole length, because the water supply might otherwise have been cut off in case of invasion. The more ancient of these two, the oldest of all the

* Abstract of lectures delivered before the School of Military Engineering at Chatham.

nine aqueducts, ran for a distance of about 11 miles. I need not say anything more about that one. When the Romans built the third aqueduct they were, it appears, no longer afraid of its being destroyed by enemies, and so they built it partly above ground, and partly underneath the ground. By the direct road to the place from which they took the water was 39 miles from Rome. Three thousand men were set to work at it under the Prætor Marcius, and so it has been called the Marcian aqueduct. This aqueduct was made so strong that the two succeeding ones were built on the top of it, so that you have the three channels one above another. The size of the channel of the Marcian aqueduct was about 5 Roman feet high by 2½ wide.* The thickness of each of the sides was a foot. You can see this aqueduct outside one of the gates of Rome at the present day.

On these aqueducts there were ventilating shafts. There were also what are known as piscinæ, or small settling reservoirs. These piscinæ I shall describe to you a little further on. Then the base of the channel was broken up by inequalities, partly to help to break the very considerable fall, and likewise to aërate the water by agitation.

I may now say a word or two about the water supply of the Roman town of Lugudunum, in Gaul. In the first place, I must remind you that those aqueducts which supplied Rome with water were carried across no deep valleys, they had, it is true, often to be supported on high arches, because they pass over low ground, and the Romans have over and over again been blamed for not using syphons ; it has been said that the Romans were not acquainted with the properties of water, in that they did not use syphons in these aqueducts. We shall see directly whether that is true or not.

The town of Lugudunum (Lyons) was supplied by water by means of three aqueducts. The first of them was built in the first century before Christ, and here is the description of it in a few words. It had two branches, which united at a particular place. It passed over a large plateau in a straight line ; then went underground. Emerging from beneath the ground, it descended, by means of inverted syphons, into a deep valley, and was received at the bottom of that valley on a supporting bridge of arches. It was thus carried across the valley, and ascended the other side into a reservoir. So you see in the course of this aqueduct, which was built in the first century before Christ, there was a large and deep valley crossed by means of inverted syphons, by the very method which we employ now ; and this shows you that the Romans then certainly understood and perfectly well appreciated the properties of the syphon.

I will now give you a description of the second aqueduct by means of which Lugudunum was supplied with water.

It was under ground the whole way, and it carried the water to a greater height than the other. The reason that it was constructed at all was, because the water was required to be carried to a greater height than the former aqueduct brought it. It was very nearly the size of the Marcian aqueduct. It was built of cubical stones placed together, as I may tell you a great many of these aqueducts were built. The stones were placed together without cement, and they fitted so accurately that some aqueducts built in this way are not even lined with cement. This aqueduct is in all probability intact at the present day for three-fourths of its length. Now we come to the third, which is the most important of the three, and which is, perhaps, the most remarkable Roman aqueduct of which we have the remains anywhere. The two former ones did not bring the water to a sufficient height. There is at Lyons an abrupt hill (Fourvières), on which several Roman palaces were built, and it was necessary to bring water to these. The Emperor Claudius, who was born at Lugudunum, and who lived there, determined to bring water on to this hill. He had already made an aqueduct for Rome (the Claudiun aqueduct), and so he knew something about it.

He had not used inverted syphons however, in his aqueduct at Rome, and for the simple reason, as you will presently see, that it was practically impossible ; but he comes and orders a new aqueduct to be built for the city of Lugudunum, and it is that one which we

* The Roman foot was equal to about 11.65 English inches.

are now going to consider, as briefly as possible.

This aqueduct descended in the first place into three or four valleys on its way. The aqueduct was 52 kilometres long, including the syphons. It had 17 or 18 bridges of arches to carry it over low grounds, and four bridges to carry the syphons across the valleys.

And now I may tell you the size of the two more important of these valleys. The valley of the river Garon, which is the second one it had to cross, is 120 metres deep, and 800 metres broad. The valley of Bonan ———, which is the next, and which is the place at which I examined the aqueduct very carefully some time ago ———, is 139 metres deep, and 1,060 metres across between the two reservoirs, which are placed one on each side of the valley. So you see these are two very considerable valleys that had to be crossed.

And now, how did the Romans manage to effect their purpose? Bridges were out of the question, although we know that they built splendid aqueduct bridges, where possible, in such situations, as witness the well-known Pont du Gard, near Nismes, which had three rows of arches one above another, supporting the channel, and which is even now so perfect that it is about to be utilized for the purpose for which it was originally built.

They used inverted syphons. I told you that earthenware pipes will not do for syphons. Cast iron pipes need to be employed for large syphons. The Romans could only work iron on a small scale and so used leaden syphons. One thing they did, and which it is important to note in this: the water was brought up along the single channel of the aqueduct—the *specus*, as it was called—which in this particular one is about 2 Roman feet broad by 6 high, into a reservoir. This reservoir had some such dimensions as 5 yards by nearly 2, and the walls were about a yard thick; there was an opening in the roof for the purpose of cleansing, and on the front side of the reservoir (the one facing down the valley), there were several holes into which the leaden pipes were fixed. Now one of these valleys had 8 leaden syphons, another 9, and another 10; and the object, of course, of dividing the water in this way was that they might get pipes that would resist the enormous pressure, and if a pipe burst the rest might remain sound, so that only part of the water would be lost. Delorme, I should tell you, has calculated that this single aqueduct brought 11 millions of gallons of water into the place in 24 hours. It is hardly likely that it brought so much as that, but it certainly brought a considerable amount.

The interior of the channels was usually constructed of very small stones carefully placed, and generally laid in cement. There was in this particular one —and probably it was so generally—a layer of cement along the walls of the watercourse, and another layer, a considerably thicker one, along the base of the channel. The arches of the bridges were built of enormous rectangular blocks of stones, and the pillars broken at certain intervals by layers of brickwork buried in cement. The whole of the exterior of this was covered over with the work known to engineers as the "opus reticulatum," which is made of cubical pieces of stone, fitted carefully together so as to give an appearance such as that indicated in the drawing (like a chessboard set up on one corner).

There is another curious thing to observe, and that is that the syphons were provided with little tubes, or valves, to let out any air that might be carried down from the height by the water, and which might otherwise break the pipes. In the smaller valleys there were small leaden tubes, which rose up from the lowest part higher than the reservoirs, and in the larger ones weighted valves were used for the same purpose. But what I want you to see in this is, that by the time the Romans constructed even the earliest of these aqueducts at Lugudunum, they knew perfectly well the properties of water. They knew perfectly well they could make it travel up to the top of a hill if it had come down a slightly higher hill on the other side of a valley. Now I just wish to give you the height of the reservoir on the one side of the valley of Bonan, the deepest of them all. The height of that reservoir above the level of the Saone at Lyons, is 151 metres, or something over that. At the other side of the valley

into which the water was received the reservoir was 143 metres above same level, that is to say, the difference in height between those two reservoirs was only eight metres. In another case, it was 9 metres. Not only then did they understand these matters so well as that, but they actually lessened this amount by causing the syphons to enter nearest reservoir—the one nearest the place to be supplied—high up close to its roof, so that they actually thus diminished the pressure by at least a metre. I have given you this description at such length, because it shows how much we have to learn from what has been done a very long time before our own age, and also because there are so few descriptions of these splendid aqueducts.

We now come to the next plan, that of having a large drainage area, and of collecting the water from that area into an impounding reservoir. Before I begin to describe this, I will give you a brief account of one or two important impounding reservoirs. The first one will be that of the Rivington Pike reservoir, which now supplies the town of Liverpool with most of its water. This Rivington Pike reservoir is calculated to supply 21 millions of gallons of water per day to Liverpool, and it has 481 million cubic feet of contents, with a drainage area of 16¼ square miles; its embankment is 20 feet high. You will see from that, that it is calculated to contain 150 days' supply.

Then there is a reservoir which was made to supply Melbourne with water, the particulars of which are given in the volume from which I quoted to you before, namely, Vol. 18 of the Proceedings of the Institution of Civil Engineers, in a paper by Mr. Bullock Jackson. It is called the Yan Yean reservoir. The description runs thus:

"The Yan Yean reservoir was formed by throwing an embankment across a valley between two spurs of hills; thus retaining the rain-water which falls on the natural basin, as well as the flood-water which is led into it in winter from the Upper Plenty River; the river itself and the artificial watercourse forming, in the latter case, a vehicle for its conduction. The area of this reservoir, when full, is 1,303 acres; the greatest depth is 25 feet 6 inches, and the average depth not less than 18 feet. Its contents measure nearly 38,000,000 cubic yards, or upwards of 6,400,000,000 gallons. The area of the natural catchwater basin, independent of the reservoir, is 4,650 acres; so that, including the area of 600 acres drained by the watercourse, there is a direct drainage into the reservoir of 5,250 acres. . . . The original surface of the ground at the site of the Yan Yean reservoir consisted of a stiff retentive clay; the site was, therefore, admirably adapted for a reservoir. Prior to the commencement of the works, about two-thirds of the whole area were densely timbered with large specimens of eucalyptus, which were taken up and burnt. The sides of the reservoir, excepting in two parts, rise in a steep slope. The embankment is 1,053 yards in length at the top, and 30 feet 9 inches in height at the deepest part; the width at the top is 20 feet; the inner slope is 3 to 1, and the outer slope 2 to 1. The inner slope is pitched with rough stones from 15 to 20 inches deep. Along the centre is a puddle bank and puddle trench, with an inner apron and check trench. The puddle trench and bank are unusually thick, because, in the first place, almost the whole of the material used in the construction of the bank was clay, so that it entailed little extra expense; but principally, because previous to the works being commenced, the site of the embankment was occupied by trees of a gigantic size, with long straggling roots, which were all grubbed up, and which it was feared might leave clefts in the soil."

According to Mr. Hawkesley, the considerations that you have to take into account in constructing impounding reservoirs are these: In the first place you have to consider the extent of the drainage area. In the second place, the amount of rainfall. And in the third place the quantity of rainfall which can be collected into any reservoir which it is practical to make in the district. The size of these reservoirs must be proportioned to the population to be supplied, their area often requiring to be ⅒ of the area of the water-shed. Mr. Hawkesley stated in a discussion, that he considered on an average of years that 30 inches of rainfall out of a rainfall of 48 inches, could be collected in an impounding res-

ervoir. It is usually considered that one-sixth part of the total rainfall must be put down as lost every year by floods that you cannot store. The water that you cannot collect is, of course, lost by evaporation from the surface of the ground, absorption by plants, and so on.

Now as to the site of the reservoir. In the first place steep-sided valleys are the best situations. In the next place, it is necessary, of course, that the place for collecting and storing water should be sufficiently high above the place to be supplied, so as to enable you to supply water by gravitation, and necessary also, that it shall not be too high above it, so that you may not have too great a rush of water.

Then besides the situation, the incline of the rocks must be considered. It is especially important in limestone that the dip of the strata shall be in the direction in which the water is running, because if the dip is against it you very often have immense quantities of water lost, disappearing between the strata and running away in another direction. Stiff impervious clay or compact rock affords the best situation. Trial shafts or borings require to be made at various places, it being better to make shafts than borings, to see if you have a sufficiently impervious material for the bed of the reservoir, and a sufficient depth of it. It is only with small reservoirs, as a rule, that you can safely puddle the whole of the bottom, or that it is done, and for this reason in small reservoirs the site is of less importance, as you can puddle the whole of the bottom, and carry it under the embankment of the puddle wall.

The embankment should have constructed what is called a puddle wall down the centre of it. I shall do well to give you some rules about this. Mr. Rawlinson lays it down, that the puddle wall is to be a foot thick at the surface of the ground for every three feet in height of the embankment, that is to say, that in an embankment 100 feet high, the puddle wall should be about 33⅓ feet thick at the base. Then it slopes up to the top so as to be about four feet broad at the top. Having decided the thickness that you are going to make the puddle wall by the height that you are going to make the embankment, according to that rule, you have then to dig what is called a puddle trench. This is dug down to a considerable depth into the impervious bed that will be the bottom of the reservoir. The trench is usually sunk with sides sloping towards one another, though this is considered by some authorities to be an insecure plan. It would involve a considerable amount of extra work, which would to a great extent be unnecessary, to sink the puddle trench with sides diverging from one another, as you would expect it ought to be, and so it is sometimes recommended to sink the puddle trench with perpendicular sides. If it is very wet at the bottom of a puddle trench, it is usual to begin filling it with Portland cement concrete, and then to go on with the puddling. For puddling only the stiffer kinds of clay are used. On each side of the puddle wall a masonry wall is built, about equal to it in thickness. The example I gave you was one in which the embankment slope on each side of this puddle wall was pretty correct, namely, three to one inside, and two to one outside. This embankment is made of such materials as can be obtained in the neighborhood, and the whole embankment must be made in very thin layers, and should be trampled in as much as possible. The inner slope of the embankment is shingled up to a little short of the water-mark, and from that point it is pitched with blocks of stones. It is sometimes necessary to make minor embankments across valleys that may join with the one you are going to make into a reservoir. Now a reservoir requires a waste weir for the storm waters. This is generally made round the end of the embankment, or cut into the hillside. The water is carried from this point down to the old stream-course, and the channel is puddled until you are well clear of the embankment.

I have one or two words to say about the reason for the existence of these impounding reservoirs, and also about the size which it is necessary to make them, and the rules that are laid down for the amount of water that they should hold. In the first place, they are necessary where a sufficiently copious and permanent supply cannot be got from a river or large stream, or from artesian wells,

in order to secure a constant supply of water throughout the year, and they do this by storing the extra supply of water during floods, so that it may be saved for use in times of drought; secondly, they allow a settling to take place; and, in third place, they are necessary to prevent damage to the lower lands by floods, for great damage is occasionally done by the floods, even of such rivers as the Thames and the Severn, and, of course, great quantities of water are wasted.

The size must depend upon the amount of water required, and upon the permanence of the supply; we have reckoned the requisite supply at thirty gallons per head per day. Impounding reservoirs should, according to the opinion of many engineers, hold a six months demand. You can tell how much that is, if you will lay down the amount of gallons which you intend to supply per head, and the population to be supplied. If possible, the gathering-ground that supplies these reservoirs should be so large that the least available annual rainfall is sufficient for the supply; and then the reservoir should contain an excess of six months demand over six months least possible supply; that is to say, supposing the least possible supply at any time during the year is zero, then the reservoir must contain six months demand. The reservoir must be (to put it in Mr. Hawkesley's words) "sufficiently large to equalize all the droughts and floods to which the country was subject. Occasionally, but not very frequently, there might be a great excess of downfall, resulting in floods as large as three or four hundred times the minimum volume." Now the minimum volume is only about an 18th or 20th part of the mean volume, so it follows, that the floods are only 15 or 20 times the mean volume.

Now with regard to compensation. It is necessary in many instances to compensate owners, mill-owners, and others, people who are interested in the streams that you are going to impound, and, on an average, it is found that in England one-third of the amount of water requires to be given as compensation to these people, and, therefore, two-thirds remain for the use of the town. This compensation, of course, must be considered in determining the size of the reservoir. Sometimes it has been arranged that the amount given to the owners on the banks should be the average summer discharge, minus the floods, and sometimes special compensation reservoirs have been built to collect the water from a certain portion of the drainage area, these compensation reservoirs being entirely under the control of the persons who are to be compensated. However, you may take it as an average, that about one-third in England generally goes to them.

The culverts have been commonly built through the embankment in the made earth. This is stated to be a bad plan. Mr. Rawlinson says they should always be built in the rock or in the solid ground, and not in the made earth. The water tower is generally built just inside of the embankment, and the discharge or outlet pipes open into it with valves, which valves ought to be inside the embankment, and not outside of it. What are called "separating weirs" have been constructed in some reservoirs. They are ingenious contrivances by which the water, when at its ordinary height, flows over the weir into the culvert to be taken away to the town. When it is in flood, the force with which it comes enables it to pass over the opening leading to the culvert, and to get away into the old watercourse. "Feeders" for diverting streams into the reservoir are also sometimes necessary. It is often found to be necessary to cut a new course for the stream that runs down the valley, especially if it be a very large stream, or if it be a stream that is liable to floods.

I see that I forgot to mention one point, which I should have stated at the beginning of the lecture, with regard to the situation of these reservoirs. The site must not be too low, for if it is, the reservoir is necessarily too shallow, and shallow reservoirs are very bad, in that the water cannot possibly be kept pure, it being perfectly impossible to store it and keep it pure in shallow reservoirs. If the ground is too high, and no other suitable place can be got, then it is necessary to make what are called "balancing reservoirs," so that the force of the water may be broken by its being kept in a series of reservoirs at different levels.

I do not profess to have given you the engineering details, as you will plainly see. All I have tried to do is to give you some of the most important points, according to the best authorities that I have been able to find.

The channels are generally made of masonry or brickwork. The water-way is, according to Rankine, best semi-circular, or a half square, or a half hexagon. These channels are usually made cylindrical; they require ventilating shafts after the custom of the Romans. Occasionally they are made with an egg-shaped section, like large sewers.

Channels require to be curved at their junctions, or at any rate, they require to be joined at very acute angles.

With regard to aqueducts, Mr. Rawlinson tells us that "aqueducts of iron will probably be cheaper than masonry or brickwork constructions." They have been made self-supporting by Mr. Simpson, by constructing them in the form of tubular iron-girders.

Now, with regard to the fall of these channels, I gave you one or two points before, when considering the pipes conveying the streams. In the discussion on the water supply of Paris, in the 25th Volume of the Proceedings of the Institute of Civil Engineers, Mr. Bateman gave the following example with reference to the Loch Katrine aqueduct of the Glasgow Water Works: "The fall was 10 inches to the mile throughout, except where the water was carried by syphon pipes across deep valleys, which, in one instance of a hollow of 250 feet, was done for a distance of 3½ miles, and in these cases there was a fall of 5 feet per mile, to economize the size of the pipes."

This aqueduct, I believe, is about the largest that has been constructed. The channel is cylindrical, and about 8 feet in diameter. Mr. Rawlinson said in the same discussion, that "the fall of an aqueduct must be in proportion to the depth and volume of water which it had to deliver. The fall of the New River in London was 1 in 10,000, or 6 inches to the mile, but with so large a volume, and an unpaved channel, it was necessary to form a weir, and give the water a vertical fall of a few inches at certain points of its course. He found that plan was adopted in the East. In laying out a line of aqueduct two principles were involved. If it were graded, as the Romans graded some of theirs, from 5 to 15 feet per mile, there would be difficulty in stopping the water at any point. It was practicable, however, to grade an aqueduct having a fall of 15 feet or 20 feet per mile, if vertical falls were introduced at intervals, alternately with level or nearly level lengths. This mode enabled an engineer to fix the velocity, so as to prevent undue washing. The vertical falls tended to aerate the water, and this in itself constituted an additional advantage. All covered aqueduct conduits should be abundantly ventilated, and there should be side entrances, stop gates, overflows, and washout valves." Sometimes in aqueduct bridges, the sectional area of the channel is diminished, and the gradient made steeper. This, of course, gives greater velocity to the water, and a smaller amount of material is required, and so less expense incurred in constructing the bridges. So much as to the masonry.

Now as to pipes. Earthenware pipes are made up to about 3 feet in diameter. If they are of compact glazed earthenware, they are very tough and strong, but they will not bear shocks, either the shocks of water or anything else, and they cannot be jointed so as to resist a great pressure, and so are not suitable for syphons. We will not say anything more about lead pipes, because they are not now used for this purpose. Cast iron pipes, Rankine says, should be of a uniform thickness; and he lays down the following rule for the *minimum* thickness: "The thickness of a cast iron pipe is never to be less than a mean proportioned between its internal diameter and one forty-eighth of an inch." But, he adds, "it is very seldom indeed, that a less thickness than ⅜ of an inch is used for any pipe how small soever." Large cast iron pipes are liable to burst, and there are some instances on record of it; one in the water works for the supply of Melbourne, which I have already mentioned once or twice, in which case the pipe was 33 inches in width, was laid through the embankment of the reservoir and burst. Now this is what Mr. Hawkesley said in a discussion on the subject at the Institution of Civil Engineers, about the bursting of cast iron

pipes: "Cast iron in the shape of a pipe would stand little unequal pressure externally, although such a pipe would bear an enormous pressure when equally distributed, whether applied externally or internally, and most in the former case, as the metal then would be under compression," and he went on to say, that at "the Rivington Pike reservoir of the Liverpool water works two lines of pipes were carried through an embankment 20 feet high, at a distance of 16 feet from the top of it. They were cast iron pipes, each pipe being made in 10 or 12 pieces, and they are the largest pipes that have been laid, each pipe being 44 inches in diameter. Now, out of these two lines of pipes, fully one-third of the pipes so placed, which were excellent castings, were broken, although they borne a pressure of 300 feet internally. The fractures invariably occurred at the top and bottom, and not at the two sides as might have been expected. The pipes being flattened and distorted by the pressure of the earth, were subjected to a strain at the top and bottom greater than at the sides, and were undoubtedly broken by compression. This fact convinced him, that pipes in that position were very insecure. Commonly, in similar cases, there was a pressure of water on the inside, and a pressure of earth on the outside; and it was a usual arrangement for the valve which shut off the water to be placed under the embankment," (that is a point I have referred to as one of considerable importance), "so that if a pipe became ruptured when in use the water would escape into the embankment, and if it found its way to the back of the puddle, the embankment would be torn down, and the whole of the water in the reservoir set free. It was not, therefore, desirable that large pipes should be laid under an embankment, where they would be subject to a considerable pressure of earth."

When a pipe of that magnitude breaks it usually does great damage. In one of these pipes that I have just mentioned to you, sixteen million gallons of water were capable of being discharged daily, and if an accident occurred, there would be a column of 44 inches in diameter, acting with perhaps 200 or 300 feet of pressure to be dealt with. Another thing about these large pipes is, that there is a considerable difficulty in repairing them. One length of these weighs about 4 tons, so that they cannot easily be dragged about or taken up. Now, cast iron pipes are said often to break from the pressure of the air. Whenever air gets driven in along with the water, and especially so in syphons where valleys are crossed, these pipes are broken (it is said) by the collection of compressed air.

Mr. Hawkesley tells us, that he considers that they are broken when the air is let out; that it is the shock caused by the running together of the two separated parts of the water that causes the breakage of these pipes, when the compressed air that is collected in them is let out too suddenly; and he recommends, and has practised in the case of those large mains at the Liverpool water works, the adoption of valves with an aperture of only $\frac{3}{4}$ of an inch; through these the air rushes out, but they do not permit the columns of water to come together very suddenly; there should be one of these at each place throughout the channel where the pipe is higher than the theoretical line, or than the line of the fall. At each one of these places air is liable to accumulate and to become compressed, and, perhaps, to burst the pipe. At each one of these places, therefore, there should be means of letting out the compressed air, and even with regard to this precaution we were, as I showed you before, forestalled in the aqueducts of the ancients.

Pipes are also sometimes burst by the pressure of the water when a valve on the main is closed; this difficulty has been overcome by a plan mentioned by Mr. H. Maudslay at the Institute of Civil Engineers: "In some instances there had been a small valve and pipe, so placed at the side of the large main as to join the main both before and beyond the large valve, in order that the whole body of water might not act like a water-ram on the closing of the large valve. This plan has been adopted in the Neptune fountain at Versailles, and also, he believed, in the mains supplying the fountains at the Crystal Palace. On shutting the large valve, the main flow was stopped, but the small pipe permitted a continuous flow of the smaller

quantity, and thus the danger of bursting was avoided. The second valve was afterwards closed gradually. He thought that this was the most simple plan that could be adopted, and perhaps the least costly, while it was certainly very effective." Another plan is that described by Mr. Hawkesley, as follows: "The value upon the main at Liverpool was divided into three openings, each of which was provided with a separate screen, so that by raising or lowering each of these slowly in succession the water was either admitted or turned off very gradually. The object of dividing the valve into three apertures was to enable a workman to operate with facility on any one of the screws. In large pipes, where the pressure was great, it was necessary, in order that the brass pieces, upon which the valve acted, might not be abraded, that only a certain amount of pressure should be put upon them, and that the friction under that pressure should not be greater than a man could overcome, by simply turning a handle, without stripping the thread of the screw. As a further provision the centre valve was made very narrow; the side valves were first closed and then the centre one, so that concussion was prevented. In addition there were branches at various points, upon which equilibrium valves, with a piston underneath, were placed, and others had double beat valves. But as these valves required to be heavily weighted, the inertia of the weight would, if other means were not taken, prevent the valve from rising so rapidly as was desirable. Therefore, between the weight and the valve there was a spring, the action of which was independent either of the valve, or of the weight, so that instead of the valve waiting for the large weight to rise, the spring immediately yielded under it and the water was discharged instantaneously. When these valves were used not the slightest shock was experienced. If there had been, the pipe would undoubtedly have been ruptured, for the length of the column, and the velocity, upon which the force of concussion was dependent, were both very great. That was another reason he preferred a smaller pipe. There were still, however, other precautions. Powerful disc-valves, made by Sir W. Armstrong & Co., and which acted in a similar way to the cataract apparatus if a small power steam-engine were placed upon the main. They were made to close slowly, being let go by a trigger. As a hundred million gallons might pass through the main in twenty-four hours, if a pipe burst, without any provision being made to stop the flow, a great deal of mischief would ensue. Supposing, however, a fracture to occur when the disc-valve was open, then the valve would gently close in about two minutes, and arrest the discharge. These valves cost £300 each. He had found them to act, on various occasions, extremely well, and but for them the country would have been flooded on several occasions."

Now, we have considered the Roman plan and also the plan of collecting water by drainage areas into large impounding reservoirs and conveying it by channels to the place that wants it, the place where it is to be distributed. When it comes there, it is collected in what are called service reservoirs. The most ancient examples of these service reservoirs are those very piscinæ, upon the Roman aqueducts, which I have spoken of, and you can see examples of them in Rome at the present day. The best I ever saw was at a place called Bona in Algeria, where is to be seen a set of the most magnificent service reservoirs. The plan was to have four compartments. The water was first let into one of the two upper ones; it then fell from that into one below, possibly over a waste-pipe. The water then passed, possibly through strainers, into another compartment on the same level, and it then rose through the roof of that compartment into a third at the level of the first one, out of which it went onwards, and a considerable settling took place. Now, there were means of scouring out these two lower compartments, which could be shut off from the upper ones so that the mud might be got out of them. The water, when it is brought to these reservoirs by either of these two methods, or when it is got into them, as it very often is now for the supply of large towns, directly out of the river, very often requires to be filtered, as mere settling is not enough for it. We have then to consider what materials are used for filtering the water,

what size the filter beds require to be, and what effect is produced on water by filtration.

Now, in the first place, the materials that are commonly used for filtration are sand and gravel. The different merits of sand and gravel and also of charcoal I shall have to consider in the next lecture, but I must conclude this lecture by telling you that the effect of filtration of water, even by sand and gravel, is not merely the mechanical effect of removing the suspended substances that the water may contain, but that, at the same time, there is a chemical action going on. This is on account of the air that is contained between the little particles of sand, which air is so brought into contact with the finely divided water that any substances in the water that are capable of oxydation do become oxydized, and a considerable amount of the organic matters in the water are thus oxydized, and transformed into inocuous matters. That is the first important point to understand about filters, whether in filtering water for drinking purposes, or with regard to a filter about which we shall have to say more after a while—a filter to purify sewer water.

I have shown you that it was a fallacy to suppose that the Romans did not understand the principle of the syphon, but that they constructed most admirable ones on the aqueducts that brought water to Lyons. It so happens, by a curious chance, that I have, recently, seen some plans and sections of the Roman aqueducts which supplied Jerusalem with water, and on one of those I find a syphon, not made with lead pipes, but a syphon made of stone. It is made of blocks of stone with a hole through each; the blocks are put together so as to form a continuous pipe. Each piece is cut at the end so that around the pipe itself, the aperture in the stone, there is a ring left projecting on the face of the stone, and that ring fits into a groove on the next stone. That made a sufficiently tight syphon to convey the water, without any great amount of leakage, to a considerable vertical depth and up again. The depth, as far as I can judge from the plans, is about 100 feet from the highest point to the lowest. Well, now, we get up to the point where the water has reached the town, and there I told you it is almost necessary, certainly usual, to construct a service reservoir. The Romans constructed them under the name of Piscinæ; and I told you, I think, in two words, how those were made; I now want to give you a rather longer account of their construction. The water that was brought by one of the aqueducts to Rome was taken direct from the river Anio, and the result of taking the water direct from the river was that after the heavy rains it was charged with mud, and though large cisterns were provided, in which, by an ingenious arrangement, much of the sediment was caught, still it was not considered satisfactory by Frontinus, who was the engineer and who, therefore, under his patron the Emperor Nerva, altered the source. Still the water that came to Rome required to have settling tanks, as described by Mr. Parker in a paper I quoted before, and from which I again quote:

"The building consisted of four chambers—two beneath and two above. Supposing, for the sake of illustration and in the absence of a diagram, the letters A B / C D represent the four chambers. The channel of the aqueduct coming from the east, at a tolerably high level enters the chamber B. Thence the water passed (possibly over a large waste pipe) into the chamber beneath, D. Between D and C there were communications through the wall (possibly provided with fine grating). Through the roof of C there was a hole, and the water passed upwards, of course, finding the same level in A as in B, whence it was carried off into another stream. By the aid of sluice gates the water could be transferred direct from chamber B to chamber A, and access was obtained by an opening to the chambers beneath, and the mud was from time to time cleared out."

Just the same thing was the case at Lugdunum (Lyons). Large settling tanks have been found on the hill of Fourvieres, consisting of two reservoirs with vaulted roofs, thus described: One of them was 48 feet long by 44 feet broad, and 20 feet high, with two conduits to admit the water, and several round holes in the roof from which it could be drawn. The walls were 3 feet thick,

lined with very hard cement. A second was 100 feet long, 12 feet broad, and 15 feet high, divided by a wall into two chambers. A third was a large one, of which five of the supporting arches remain, and the discharge conduit, 1½ feet broad, which distributed the water, by means of leaden pipes (of which a specimen has been found) to the palaces, gardens, etc. In some cases similar constructions formed public reservoirs from which the people drew the water. In Rome "there were 591 open reservoirs (lacus) for the service of all comers. * * * These reservoirs were what we usually speak of as fountains; and some hundreds are in use to this day, many probably on the site of the older ones. There were very stringent laws respecting their use. Heavy penalties were inflicted upon any one dipping a dirty bucket or vessel into the reservoir. There were also laws respecting the 'overflow,' as the fountains, of course, were constantly running; these were the most important to keep in order, as all the poorer classes depended entirely upon them for their supply of water."

Now let us consider the Service Reservoirs as they are made now. Service reservoirs must either be placed at a low level, so that the water has to be pumped from them, or high up, which is better, so that the water, if not brought to them at that level, is pumped into them, as at Lyons, on the Rhone, where the water is brought to them at the highest point. They are made to contain a few days' supply. In the first place, they must always be covered; even the Roman ones were. The reason of there being covered is that, if not covered, the water becomes impure, for the impurities of the air dissolve in the water and the growth of confervæ is also, of course, very much aided by light. If they are at the level of the ground, they are built of masonry.

Mr. Rawlinson says, "The ground excavated for the foundation of a tank should be made perfectly water-tight. The bottom may be covered with clay puddle and the side walls be backed or lined with clay puddle. The thickness of the puddle should not be less than 12 inches. If the site selected for a tank is sand, gravel, or open jointed rock, great care must be taken to give the puddle a full and even bearing over the whole surface area; open joints in rock must be cleaned out and then filled up with concrete. In gravel, large stones must be removed and the entire surface brought to a level, smooth, and even plain. Clay puddle will only resist the pressure of water when it rests solidly on an even bed, so as to prevent the water forcing holes through it, which will be the case if there is a rough uneven surface and open space beneath." (*Suggestions as to the preparation of plans as to Main Sewerage and Drainage and as to Water Supply.*)

The roof is supported on piers with arches between them, and across sometimes iron columns are placed in rows supporting the girders which carry the arches. The supply pipe has one or more exits, a waste and a wash-out, which may be connected by valves so that the supply can be directly connected with the exit independently of the tank.

[Drawing exhibited.] That gives a general idea. The water is received in a sort of well or tower through which it passes into the tank, and after settling has taken place it passes out through a valve into the exit pipe. When the supply is too great it is carried off by an overflow to which the wash-out pipe may be jointed.

Well now, I should like to give you a more detailed description of such reservoirs, and I take as an instance, and that for several reasons, the description of some reservoirs with supply tanks:

"The reservoir of Passy is intended to receive the waters pumped from the Seine at Chaillot, and those furnished by the Artesian well of Passy when disposable; it is composed of three compartments, two of which are covered by a second range of arches, the third, intended as a reserve in case of fire, being deeper than the rest, and only of one story; the two upper ranges of arches, also, are to be made to hold a supply of water, one of them being covered and the other not. The united capacity of these various compartments is 9,227,097 gallons, and their levels above the Seine are respectively arranged at 150 feet, and 163 feet, above zero of the scale of the bridge of la Tournelle. The capacity of the separate reservoirs is, for those

nearest to the ground, respectively 2,232,800 and 2,344,984 gallons; these are covered with reservoirs of the capacity of 1,282,792 and 1,495,729 gallons; and the uncovered side portions of the reservoir are devoted to the remaining 870,792 gallons. These buildings are formed on the 'tuf du calcaire lacustre,' which afforded a hard, resisting foundation, and did not require any particular precautions to prevent the subsidence of the piers, or to secure the water tightness, or the impermeability of the bottom. The external walls have been in consequence carried down to the depth of 8 ft. 4 in. and have a width of 8 ft. 8 in. all around. The floors are of masonry, 1 foot thick in meuliere and cement, covered with a rendering coat of 1¼ inches of the same cement worked to a fine face. This is covered with a range of cylindrical vaults of 10 feet opening, springing from pillars 2 ft. 8 in. square upon the top, gradually enlarging to 5 ft. at the bottom. It is calculated that in no case does the weight brought upon a square inch of this masonry exceed 152 lbs. The thickness of the arch forming the roof of the first tier, and the floor of the second division, is about 1 ft. 2 in. on the crown; that of the roof of the upper division is only 4½ inches, executed in two courses of tiles bedded in cement, and 'rendered' with a coating of that material and covered with concrete.

"The reservoirs of Menilmontant are considerably larger than those of Passy, and being founded upon the upper members of the Paris Basin, special precautions were required to insure that the ground should not yield under the combined pressure of the masonry, and the 29¼ million gallons of water intended to be stored. The marls covering the gypsum of which the mountain of Menilmontant is composed, were not considered to be able to withstand that weight. The foundations of the piers were therefore carried lower down, and thence built in a description of rough rubble of menliere set in hydraulic lime. The bottom floor of the reservoir is arched over these piers, and the upper tier of arches rests upon this floor."

It is only fair to tell you that some engineers, and among others, Mr. Rawlinson, considered the plan of building two-storied reservoirs as a bad one, and not to be imitated; but it necessary to know that there is such a plan, and the description applies, to a great extent, to all reservoirs.

To take an example nearer us, there is Mr. Simpson's elevated reservoir on Putney Heath; that contains ten millions of gallons altogether. There is there a double covered reservoir to contain filtered water for domestic use, and a smaller open one to contain unfiltered water for the streets, and to supply the Serpentime, and so on. So that you see it is usual in these cases to build several reservoirs together. This covered reservoir that has to contain water for domestic purposes, is double, or constructed in two halves. Each part has an area of 310 feet by 160 feet, and a depth of 20 feet. The sides all round have a slope of one to one. This gives a mean area of 290 feet by 140 feet, and a capacity of about 5,075,000 gallons for each reservoir, exclusive of the space occupied by the piers. "Hence the whole capacity may be taken" as stated by Mr. Simpson in his evidence, "at 10,000,000 gallons. The sides of the reservoir are cut out in the form of steps, which are filled up with concrete to a uniform slope of one to one; and a bed of concrete one foot in thickness is also laid over the whole bottom; each half of the reservoir is covered with eight brick arches, averaging rather less than 20 feet span, the arches being each 20 feet span, and the others 18 ft. 8 in. Two piers supporting these arches are built lengthways, and are each 310 feet long at the top, and 270 feet at the base. The arches are each one brick in thickness, and are covered over with a layer of puddle, the haunches being filled up with concrete. The piers are carried out 14 inches thick; but the division wall between the two parts of the reservoir is rather more than four feet thick, with a concrete slope of one and a half to one on each side. The 14-inch piers supporting the arch are built with large circular hollows 17½ feet diameter. The centres of these circular hollows are 40 feet apart, so that solid brickwork 23 feet long is left between the circular hollows, supposing a horizontal section taken through the centres of the hollows. Each of the 23 feet spaces has a 14-inch

counterfort carried out at right angles. These counterforts occur at intervals of 26 feet and 13 feet alternately, and project 6 feet wide at the base, on each side of the pier, and run out to nothing at the top, or springing of the arches." "The versed sine or rise of the arches is 4 ft. 3 in., or rather more than one-fifth of the span. Each arch is provided with two openings in the centre, communicating with a line of 12-inch earthenware tubular pipe, which passes through the spandrils and communicates with perforated iron tops in the division wall between the two parts of the reservoir. By this contrivance the space above the water in the covered reservoirs is effectually ventilated. The supply pipe from Thames Ditton is 30 in. in diameter and comes into each part of the reservoir at the level of top-water, which is a few inches below the springing of the arches. At this level a waste weir, or overflow, is fixed to prevent the reservoir being filled too full. The exit mains to London consist of two 24-inch pipes, and they pass from the bottom of the reservoir, which has an inclination in one direction of 1 in 20, and a fall across of six inches." (Hughes on "Waterworks:" Weale's Series.)

Now a great reason for the existence of these service reservoirs is, that the hourly demand during the day varies very much from the mean. It is sometimes so much as three times the mean demand, during certain hours, so that by this means it is not necessary for the mains to be made inordinately large. But otherwise the mains would have to be made large enough to give the greatest demand, instead of being only sufficient for the mean demand. And this is the case if the reservoir is only large enough to contain half the daily demand. In that case the distributing pipes need only to be calculated to give the greatest hourly demand. These you will recollect are under ground tanks. Elevated tanks are sometimes made of cast iron, or wrought iron plates bolted together, and tied by wrought iron rods at the bottom, to one another. The supply, exit, and overflow pipes ought to be together in a corner of the reservoir, in a small separate compartment. This separate compartment is connected with the main reservoir by a valve, so that the main reservoir can be cleaned out and the supply go on independently of it. Thus you can shut out the supply, stop pumping, open a valve, and let out all the water from the large reservoir by the supply pipe to the town. Then you can close the valve and let the supply go on through this little separate reservoir, while the other is being mended or cleaned out.

The overflow pipe, or waste pipe, or whatever you like to call it, ought to open into an open channel, and not be connected, as is very frequently the case, with the nearest drain or sewer. It ought to open above ground, because as the reservoir is covered, if it does not do so, the foul air from the drain will come up that waste pipe, and be dissolved by the water in the cistern, and so you will render the water that you have taken so much trouble to get pure, you will render it impure, and that is what is continually done in all towns, and in houses, as I shall tell you presently when speaking of sewerage.

For distributing basins or tanks, Rankine says, that "the most efficient protection against heat and frost is that given by a vaulted roof of masonry, or brick, covered with asphaltic-concrete, to exclude surface water, and with two or three feet of soil, and a layer of turf." Mr. Rawlinson says, that "brick and masonry tanks, if arched, may be covered in with sand, or fine earth, to the depth of 18 inches, which will preserve the water cool."

Up to the present time we have been describing works connected with impounding reservoirs; now, with regard to river works. With river works you still more certainly require settling reservoirs into which water may either flow directly through culverts from the river, as it does at Chelsea, or into which it may be pumped. When the water flows in from culverts, you require almost invariably to have filter beds, which we shall describe a little further on. Sometimes for river works it is necessary to construct a weir right across the river, in order to keep the water as near as may be at constant level. The engine power employed ought to be considerably greater than that which is actually wanted, one-third greater at any rate, and of course there ought always to be

a reserve engine. At the Chelsea works, to which I have before referred, the depositing reservoirs are made in London clay, and the bottom and sides are merely lined with cement placed upon this clay. From this the water passes direct to the filter beds.

With regard to those cases in which the water is taken from rivers, there are certain things I want to tell you. I want to tell you something about the purification of river water. We know that into rivers, especially in thickly populated countries, an enormous amount of refuse matter of all sorts is thrown, and it is necessary to know whether this refuse matter is destroyed in its passage along the rivers, that is to say, whether the water, after running a certain distance, becomes sufficiently pure to be used for drinking. And now I must quote to you from a book from which I shall have occasion to quote a great many times during the course of the remaining lectures, a book entitled "A Digest of Facts relating to the Treatment and Utilization of Sewage."

"The evidence collected on this head by the Royal Commission on Water Supply was very various. Dr. Frankland says :

'There is no process practicable on a large scale by which that noxious material (sewage matter) can be removed from water once so contaminated, and therefore I am of opinion that water which has been once contaminated by sewage or manure matter is henceforth unsuitable for domestic use.'"

Now the results of experiments are found to give the following facts :—In the first place it appears that in rivers that are well known to be polluted, and the water of which has a temperature not exceeding 64° Fahrenheit, a flow of between eleven and thirteen miles "produces but little effect upon the organic matter dissolved in the water." To remove all uncertainty from the "variability of the composition of the river waters at different times of the day," experiments were made by mxing filtered London sewage with water; "it was then well agitated and freely exposed to the air and light every day, by being syphoned in a slender stream from one vessel to another, falling each time through three feet of air." The mixture which originally contained in 100,000 parts .267 of organic carbon and .081 of organic nitrogen was found to contain, after 96 hours, .250 of organic carbon and .058 of organic nitrogen ; and after 192 hours ; .2 of organic carbon and .054 of organic nitrogen. The temperature of the air during this experiment was about 20 deg. cent. (68° Fahrenheit). "These results indicate approximately the effect which would be produced by the flow of a stream containing 10 per cent. of sewage for 96 and 192 miles respectively, at the rate of one mile per hour." They show then, that at the above temperature, during a flow of 96 miles, at the rate of one mile an hour, the amount of organic carbon was reduced 6.4 per cent., that of organic nitrogen 28.4 per cent.; while during the flow of 192 miles, at the same rate, the amounts of these two substances were only reduced 25.1 and 83.3 per cent. respectively. It is shown that the oxydation of this organic matter is chiefly affected by the amount of atmospheric oxygen dissolved in the water, "such dissolved oxygen being well known to be chemically much more active than the gaseous oxygen of the air."

It was found, however, that the action of this dissolved oxygen was not really anything like so quick or so perfect as generally supposed, and that 62 per cent. of the sewage was the maximum quantity that would be oxydized during 168 hours, even supposing that the oxydation took place during the whole time at the maximum rate observed, which was certainly not the case.

"It is thus evident, that so far from sewage mixed with 20 times its volume of water being oxydized during a flow of 10 or 12 miles, scarcely two-thirds of it would be so destroyed in a flow of 168 miles at the rate of one mile per hour, or after the lapse of a week. . . . . Thus, whether we examine the organic pollution of a river at different points of its flow, or the rate of disappearance of the organic matter of sewage when the latter is mixed with fresh water and violently agitated in contact with air, or finally the rate at which dissolved oxygen disappears in water polluted with 5 per cent. of sewage, we are led in each case to the inevitable conclusion that the oxydation of the organic matter in sew-

age proceeds with extreme slowness, even when the sewage is mixed with a large volume of unpolluted water, and that it is impossible to say how far such water must flow before the sewage matter becomes thoroughly oxydized. It will be safe to infer, however, from the above results, that there is no river in the United Kingdom long enough to effect the destruction of sewage by oxydation.

Now there were several scientific men who gave evidence of another sort, and who declared that practically speaking water was sufficiently pure after even a short flow. The answer to that statement is found if we just go into a few of the public health facts. Here is one. This is gathered from Mr. Simon's report on the cholera epidemics of London in 1848–49 and 1853–54. "When the Lambeth Company took its water from the Thames near Hungerford Bridge, the people who drank that water died at the rate of 12.5 per thousand. When the source of supply was moved to the Thames at Thames Ditton, the mortality was only 3.7 per thousand, while at the same time, and in the same districts, the mortality among the people who were supplied with water by the Southwark Company from the Thames at Battersea was at the rate of 13 per thousand."

I could give you any number of facts of that sort to show you that water that has been polluted is dangerous to drink. I may just mention to you the opinion which Sir Benjamin Brodie, the late Professor of Chemistry at Oxford, has given; he said in his evidence before the Rivers' Pollution Commissioners:—"I believe that an infinitesimally small quantity of decayed matter is able to produce an injurious effect upon health. Therefore if a large proportion of organic matter was removed by the process of oxydation the quantity left might be quite sufficient to be injurious to health. With regard to the oxydation we know that to destroy organic matter the most powerful oxydizing agents are required: we must boil it with nitric acid and chloric acid, and the most perfect chemical agents. To think to get rid of organic matter by exposure to the air for a short time, is absurd."

I give you those statements in order to bring you to the conclusion to which I wish you to come, namely, that we should not take water for the supply of villages and towns, from a river that has been contaminated at all, if it can possibly be helped; that it has never been proved that such water gets really pure again; and that at certain times therefore very considerable danger may arise from drinking such water; in fact as Mr. Simon said when examined before the Royal Commission on water supply "it ought to be made an absolute condition for a public water supply that it should be uncontaminable by drainage."

The water when taken from the river, or even if it is taken from the gentle slopes of cultivated lands, and also in some other instances, requires to be filtered as well as allowed to settle; deposition is not sufficient of itself. It is important, also, to keep out inferior waters, that is when there are several sources; and with this condition, you may prevent the necessity of the water all requiring to be filtered.

Mr. Parker says:—"At last it may be interesting to know what Frontinus did, or rather, what he says with becoming modesty, his patron, the Emperor Nerva, accomplished on this score: 'But the water of the Anio Novus often spoilt the rest, for since it was the highest as to level, and held the first rank as to abundance, it was most often made use of to help the others when they failed. The stupidity, however, of the Aquarii was such that they had introduced this water into the channels of several others where there was no need, and spoilt water which was flowing in abundance without it. This was the case especially as regards the Claudian, which came all the way for many miles in its own channel perfectly pure, but when it reached Rome and was mixed with the Anio it lost all its purity. And thus it happened that many were not in fact helped at all by the addition of the extra water, through the want of care on the part of those who distributed it. For instance, we found even the Marcian, the most pleasant *to drink* on account of its brightness and freshness, in use in the baths, and by the cloth-fullers, and according to all accounts employed for the most base services. It pleased, therefore, the Emperor to have all these separated, and for each to be so arranged

that first of all the Marcian should be assigned *to its own use*, so that the Anio Vetus, which from various reasons was found to be less wholesome, as well as being at a low level, should be employed for the watering of the gardens in the suburbs, and in the city itself, for viler purposes.'"

So you see they had, even then, found out that one water was more wholesome than another, and when they had got supplies from two or three sources they knew it was better to keep them separate, and so use the best one for drinking purposes and the inferior ones for other purposes.

Now when water containing substances in suspension is passed through a medium provided with fine pores, it is, of course, at least the purer by virtue of the removal of all such matters as are unable to pass through the pores. If that were all that filtration accomplished, it would be only a fine straining process. But that is not all. If you take a large quantity of porous material, for instance, a large mass of sand, or gravel, or especially charcoal,—almost any porous material,—and pass water through it, water containing certain substances in solution, and certain substances in suspension, those in suspension will remain unless they are fine enough to pass through the pores of the material. But all these porous substances contain an immense amount of air between their pores, and the water by being passed through them is divided into an infinite number of exceedingly small rivulets, exceedingly small streams, and so the substances in solution in the water are brought into the closest possible contact with the oxygen of the air between the pores of the filtering material, and so when you have passed the water through a filter, a chemical action takes place, and not merely a mechanical action. You have a mechanical action first, and then you have also a chemical action. That chemical action consists in the oxydation of the substances held in solution in the water—that is, such substances as are capable of oxydation, and these are the ammonia and the putrescible organic matters which are so dangerous when left in drinking waters.

One of the best filtering substances, that is, one which alters the substances contained in water most in its passage through it, is animal charcoal, and you will find in the 26th and 27th Vols. of the *Proceedings of the Institution of Civil Engineers*, a most important and interesting discussion on this property of animal charcoal, and other substances—sand, and so on—upon the power of these materials to cause the oxydation of substances in water. I should tell you that the paper itself to which I refer in that 26th vol. is not worth reading, but the discussion afterwards is very well worth careful study. The paper is worthless, because it came to an entirely erroneous conclusion on account of the experiments being performed by a process which is practically worthless.

Here I must give you an example. Dr. Frankland tells us that he filtered New River water through animal charcoal; that before filtration it contained in solution about 18 grains in a gallon of solid matters, that after filtration it contained 11.6. Of course you are prepared for a less amount of impurity after filtration. Now the organic and other volatile matters contained in the water before filtration amounted to .37 of a grain in a gallon, and after filtration the amount was 15; that is to say that more than one half of these matters were removed by filtration through animal charcoal. After a month this charcoal removed still more organic matter, and some mineral matters as well, and even a few months afterwards one half of the organic and volatile matters only remained after filtration. These experiments show a very important thing, which is perfectly true of a sand filter as it is of an animal charcoal filter, and that is, it is not by storing up these matters that a filter works, or else it would be of no use whatever to make a filter. You would have it choked up in a very short time, and it would continually have to be renewed, whether made of sand, of gravel, of charcoal, or what not. It is by oxydizing the substances that the advantage is obtained, and the results of oxydation you can find in the water afterwards, and these results of the oxydation are nitrates and nitrites, and carbonates. Of course these are harmless matters, and that is the important action which a filter has. Dr. Frankland stated that he had passed the water supplied to

London by the Grand Junction Company through a thickness of three feet of animal charcoal, at the rate of 41,000 gallons per square foot per day of twenty-four hours, under a head of water of thirty feet, the charcoal being in granules like coarse sand, and that at that rate—a tremendous rate—more than one half of the organic matter was removed. He thought from these experiments on animal charcoal that persons who had to supply water to towns ought to use it, as at any rate one of the media in the filter beds. I must not pass from charcoal without mentioning that vegetable charcoal is agreed on nearly all hands to be almost entirely useless for purposes of filtration. In the first place it contains enormous amounts of salts which are soluble in water, so that the water becomes very much harder in passing through it than before, and then it does not purify water in the way that animal charcoal does.

Well, now some of the effects of sand filters, as employed by the Water Companies, Wanklyn points out. He says that the Thames water at Hampton contains fifteen parts of albuminoid ammonia, or ammonia derivable from organic matter, in one hundred millions, that is to say .15 in 100,000, which is the way we have generally reckoned it, and that after filtration by the company it only contains 5 or 6; so that you see water is capable of being purified—that is, the matters in solution are capable of being altered in drinking water on an immense scale.

Now what sort of things are these filter beds, as they are made, because laboratory experiments are all very well, but you have practically, to do it on a large scale. Mr. Hawkesley has made some large waterworks, as you are most of you probably aware, at Leicester, and there, there is a reservoir of forty acres in extent. There are also four filter beds, each ninety-nine feet long, and sixty-six feet wide, and eight feet eight inches deep from the ground. The water comes in separate channels to these filter beds, and it is passed downwards through the following filtering materials:—Two feet six inches of sand, and then two feet six inches of layers of gravel of various sizes (from the size of beans up to eggs) to the drains below and thence by pipes into an octagonal pure water tank. This tank, eight feet eight inches deep, holds seven feet eight inches of water, and is sixty-six feet from side to side. That is the general plan.

The supply comes to the filter beds from the reservoir at various points; it passes through two feet six inches of coarse sand—for, it must be observed, fine sand will not do, as it gets choked up by the suspended matters in the water—and then through two feet six inches of gravel. The filtering beds have sloping sides and are made of sand, fine gravel, coarse gravel, then very coarse gravel, with a drain at the bottom. The filtered water is delivered into an upright pipe in the tank, which comes within two feet of the top, so that the pressure of the water on the beds from above can never be greater than that due to a height of two feet. It is essential that the pressure on the surface of the beds should not be too great.

Well now from these filters six hundred or seven hundred gallons per day per square yard flow, and the proper rate of vertical descent for the water, as it is generally considered, is six inches per hour, not more, or sevent-five gallons per square foot in twenty-four hours, and that you see is about the rate at which it passes through these last named works; now the effect at this particular place is that the water is clarified, and a considerable proportion of the organic matters in solution are removed from it. The sand of the surface of the filter beds requires scraping from time to time and also renewing.

At the Gorbals Filtration Works near Glasgow, the filtering materials are placed in vertical compartments with passages between them, in each of which the water rises to nearly its original level and then flows over into the next compartment and down through the filtering material in it. There are two other plans I must mention, at Blackburn, for instance, there is no filtration. There they have a service reservoir, and they take the water out of it from the top by a sort of process of decantation. They let it settle, and then take only the water from the top. Another plan is in practice at St. Petersburg. There the water is made to fall down a series of

steps, and then through wire gauze, and lastly through sand filters, and by these means the water which is generally very impure is rendered tolerably pure and a considerable amount of putrescible organic matters are collected from this wire gauze.

Now we have to consider briefly the ways in which water may be distributed in towns. In the first place, as to the mains: their size must be calculated according to the supply required.

Mains are often made in towns on both sides of the streets in order that the supply may not be entirely cut off during repairs. There must be means provided by which the water may be stopped in a main in order that it may be repaired. The bends and junctions should always be curved. There should be no junctions made at right angles, and there should be no angular junctions if it can be helped. Mains should be made of cast iron. They should be greater than 3 inches in diameter. The best service pipes for houses are $\frac{3}{4}$ in., or 1 inch wrought iron service pipes that screw together. They are better than lead, and they are likewise cheaper than lead. Wrought iron pipes are better than lead for this reason, that certain kinds of water act upon lead. Soft water is apt to act upon lead. Fortunately, hard waters, containing a considerable amount of carbonic acid, act very little on leaden pipes, and so it is the practice very frequently to have leaden pipes and cisterns made of lead, and practically very little harm results. If you refer to the 25th Vol. of the "Proceedings of the Institution of Civil Engineers," you will find a discussion on water supply, and there you will see that Mr. Bateman gave it as his opinion that even soft water acted very little indeed on leaden pipes, after a time. It acts on them at first, but the leaden pipe or cistern soon gets covered inside with an insoluble coat of subcarbonate of lead, and the result is that afterwards the water acts very little on it. The water of Loch Katrine, which is supplied to Glasgow, acts very little on the leaden pipes and cisterns used. However, there is no reason for having lead if danger be apprehended as likely to result; wrought iron will do just as well and is cheaper.

A town may be supplied in one of two ways. These two ways are known as the Constant and Intermittent systems. First, there is the *Constant system*, in which, of course, the mains are always full and the water is brought into the houses by pipes from the mains, no cisterns being needed, as the water is always in the pipes, and you have only to turn a tap in order to get it. Secondly, there is the *Intermittent system*, in which the water is only supplied for a short time during the day, and in this Intermittent system it is therefore necessary to have cisterns in the houses. Now as to the relative advantages and disadvantages. Professor Rankine says: "The system called that of *Constant service* according to which all distributing pipes are kept charged with water at all times, is the best, not only for the convenience of the inhabitants, but also for the durability of the pipes and for the purity of the water; for pipes when alternately wet and dry tend to rust, and when emptied of water they are liable to collect rust, dust, coal-gas and the effluvia of neighboring sewers, which are absorbed by the water on its re-admission. In order, however, that the system of Constant service may be carried out with efficiency and economy, it is necessary that the diameters of the pipes should be carefully adapted to their discharge and to the elevation of the district which they are to supply, and that the town should be sufficiently provided with town reservoirs. When these conditions are not fulfilled, it may be indispensable to practise the system of *Intermittent service*, especially as regards elevated districts, that is to say, to supply certain districts in succession during certain hours of the day." You see, therefore, that Professor Rankine emphatically condemns the system of Intermittent service as compared with that of Constant service.

Now the great objection to the system of Intermittent service is the necessity of having cisterns, whatever they are made of. Water becomes impure in cisterns, dust collects in them, and the cisterns require frequently to be cleansed. If this is not done the water may even become dangerous to drink. Where cisterns are necessary, slate cisterns are the best. They require to be made with

good cement, or they are apt to leak, and then you are liable to get red lead or something of that sort used to fill up the joints, and so you get the water tainted. Iron rusts, and for that reason cast-iron mains require to be varnished inside and out. Zinc has been used for cisterns and also for pipes, but zinc often contains lead, and cases have been known of lead-poisoning having resulted from the use of zinc pipes or cisterns. There have been plenty of ways proposed for coating lead pipes so that the water may not act upon them. Several of them are absolutely objectionable; one of the methods, for instance, was the use of a varnish containing arsenic; and even other varnishes which do not seem to be objectionable, are not now practically used.

If you look in Vols. 12 and 25 of the *Proceedings of the Institution of Civil Engineers*, you will see a great many arguments for and against both the "Constant" and "Intermittent" systems, and one argument against the "Intermittent" system is always that the amount of waste is enormous. It is stated as you will there find, that at that time the amount of water wasted in London was something like half the supply. You find it alleged that there is great waste also on the Constant system, because, it is said, the mains are always full and the taps are apt to be left running. But this may be provided against by having the taps placed inside the houses, and then you will be quite sure there is not much waste. Then, the waste that has been observed with the Constant system has been mostly caused where the Intermittent system has been changed for the Constant system, and in that case you do sustain a loss of water; a loss on account chiefly of faulty pipes, and leaky fittings, for such as may do very well under the Intermittent system are not good enough to be employed for the Constant system. In Liverpool, at a particular date, there were used 33,000,000 gallons of water a week, in the supply of which only 1,000,000 gallons were supplied on the Constant service, and the whole of the remaining 32,000,000 gallons were on the Intermittent service. For some weeks, as an experiment, three-sevenths of the town were put on the Constant service, and then the amount of water used rose from 33,000,000 to 41,000,000 gallons per week. But where there has originally been sufficient attention to the fittings, and where they are strong enough it is otherwise. For instance, in the case of Wolverhampton, at the same period, it is stated that in that town there was a saving effected by changing from the Intermittent to the Constant system, a saving of no less than 20 gallons per head per day. (Vol. xii., p. 503.)

A disadvantage of the Constant system is that the water supply sometimes runs short in the higher parts of the town, while in the lower parts there is a sufficient supply; so that cisterns would sometimes need to be provided, even under the Constant system, in these higher parts of the town.

As a summary: with the Constant system the waste of water is certainly less than with the other if the fittings are properly attended to, and if the fittings, pipes, &c., have been originally arranged for the Constant system. The water in the case of the Constant service is purer and fresher, and at a lower temperature in summer, and less subject to frost in winter. The water is purer because it escapes the impurities which I have already pointed out, as collecting in pipes, and it also escapes those impurities which the water gets by being stored in cisterns.

The inconvenience from interruption to the supply during repairs is never actually experienced, as the interruption need only be for a few hours. On the other hand, the interruptions and the waste caused by neglect of turncocks, by the limitation of the quantity of water, by leaky taps and cisterns, and in other ways—these inconveniences are absent. Then the leakage from pipes is less. In the Constant service the pipes are made stronger, and practically there is much less bursting. Mr. Hawkesley states that the difference between the systems is a question of pipes and fittings, and that when the supply is well managed the waste under the Constant system is less.

Then the water supply should always be to the top of the house, and if possible, to each story of the house. If cisterns are necessary those used for drinking water should always be separate from

any other cistern in the house, If, for instance, there is a cistern for the water closet, it should be entirely separate from the cistern used for the storage of drinking water; there should be two separate cisterns. Then a chief point to attend to with regard to the drinking water system is that it should be covered. Secondly—That it should be easily accessible, so as to be readily cleaned out: and thirdly—and this a most important point—that the waste pipe from it should empty out into the open air either over the surface of the yard or over a roof or into a rain water pipe, which itself does not go down into a drain. The waste pipe should on no consideration be connected with any water closet apparatus or with drains. This is almost invariably done, and that is why I insist so much on the importance of this point.

I may tell you that one of the most frequent causes of typhoid fever in London at this moment—of this I have not the slightest doubt—is that the waste pipes from the drinking water cisterns are connected with some part of the sewerage apparatus, and very often directly with the sewers. The house drain, more frequently than not, being unventilated, the waste pipe of the drinking water cistern, becomes the ventilator of the house drain, and the foul air of the house drain goes up into the space between the surface of the water and the lid of the cistern and is absorbed, and the result, in many cases, as I have frequently observed, has been a severe attack of diarrhœa through the whole household, or else of typhoid fever, and I have no doubt in some cases of cholera also.

The overflow pipes from other cisterns we need not be so particular about, because we do not require to drink the water; but it is just as well that they should empty in a similar way if possible. If not, they may be made to end in what is called the D trap of the water closet. I shall explain that, however, more fully further on.

Now we have brought the water into the house—either into the cisterns, or it may be, merely into the pipes, which are kept constantly full, and which have taps at various levels inside the house. When inside the house, it may be purified still further, if necessary, by household charcoal filters, or by boiling and then being left to stand in stone vessels. That is an excellent plan, and I must tell you here, that impure water may be purified to a very considerable extent by making an infusion in it: for instance, an infusion of tea. This is very important for you to know when you may have to drink water in marshy countries. A great deal of mischief is sometimes done by drinking water in marshy countries, and this mischief may be prevented by merely boiling it. That is a very good thing, but still it is better, on the whole, to make a weak infusion of something like tea, in it, and that is the system which has been practised for a thousand years in China.

MARITIME ATTACK BY TORPEDOES.

From "The Engineer."

Nearly at the close of the Crimean War, just twenty years ago, the first attempt at ironclad ships of war appeared before Kertch, in those floating iron boxes the Meteor and Thunder, built like the corresponding floating batteries of our allies, from designs suggested by the Emperor of the French, which latter were carried out under his naval constructors. These proved themselves invulnerable to 32 lb. round shot, at very short ranges; and there was not wanting on our parts some self-congratulation that our great iron-making country must derive from the discovery a new lease of our maritime supremacy. About the same time the first real achievements in the way of perfecting a system of heavy rifled artillery began to appear, by the adoption of ringed structure for guns in wrought iron or steel, and with these the prediction of Robins, that the nation that first produced an effective system of rifled fire-arms and artillery would—on land, at least, and for a time—out-distance all competitors in warfare, seemed about to

be realized. It has been realized, to a vast extent, upon land, and, together with the railway system, has permanently changed the former methods, tactical and strategic, of European warfare.

The idea of stopping a cannon shot by an iron plate probably never entered the sagacious brain of Robins—who lived in the pre-iron age ; nor could he have had any conception of the rapid and powerful progress of invention and mechanical power which characterize our epoch. From 1854 to the present hour the unforeseen contest of gun against plate has been uninterrupted ; though with little more recondite scientific base for the contest than the obvious fact that a thicker plate could still be pierced by a bigger gun than before ; and millions have been expended, and to a large extent wasted, in simply repeating upon a larger and larger scale this almost self-evident truth. From time to time scientific artillerists, engineers and naval constructors, have speculated upon whether the final victory would rest with the ponderous armor-clad, or the enormous artillery it was proposed to carry ; and, viewed from a scientific point alone, those were most nearly right who declared that the gun must be the final victor, by its almost limitless power of penetration or dislocation—the thickness of possible armor-plating being limited by the size of the ship to carry it not surpassing that which should be manageable in narrow waters, and in the perils of sea and weather. The stages at which the duel of plate and gun have arrived during the last few years have brought, in a more or less distinct form, before the minds of men regarding the subject with a larger view than that afforded by science only, that the contest at last, if carried on on previous principles, must draw near its close, and eventually be decided, not, perhaps, in favor of either plate or gun, but by the correlative conditions and financial or economic eventualities which the enormous increase in magnitude of both must give rise to.

The means of attack and of defence as they have been enlarged have inevitably led to our being compelled to put "too many eggs into one basket." We have come on the one side to armor of 2 feet thick, and costing probably for material alone in place £600 the square fathom, to say nothing of the cost of the ship to carry it, so that the destruction of a single iron-clad, carrying only a few ponderous guns, would involve a national loss in war material exceeding the value of many a naval squadron deemed powerful in Nelson's day. On the other hand we have arrived through the gradual stages of twelve, eighteen, twenty-five and thirty-five ton guns, at length at those of eighty tons, the first of which is now in progress at Woolwich. The actual outlay for the production of this first enormous gun, including new forges and forty-ton hammer, steam and hydraulic cranes, special furnaces, coil rolling and bending machinery, gigantic tongs of thirty tons weight, and a multitude of minor paraphernalia, will probably be little short of £100,000. If we assume that the gun itself shall ultimately prove a success—and in the hands of Colonel Campbell and Mr. Fraser we see no great reason to doubt this—then it would be unfair to charge the whole of this to the first gun, though nobody can predict what additional expenses in the way of plant the experience to be obtained hereafter from the first gun may suggest or necessitate. The estimated cost, however, for wages and material alone for the production, as stated on authority, of this first gun amounts to £6,500; and bearing in mind the margin which experience proves always exists between estimated and actual costs in all new and arduous engineering undertakings, we may safely assign from £10,000 to £12,000 as the cost of this single gun, and that with the ship that is to carry it, the gun-carriage, mechanical means of training and loading, and the many other paraphernalia that such a piece of artillery will entail before it is ready to be discharged against an enemy, the entire apparatus will stand in our national ledger at from £300,000 to perhaps half a million. Yet the very idea inseparable from these gigantic conceptions is that the chance of a single successful shot from either the attacking or attacked ship must in all probability disable or send her opponent to the bottom. Such is the swift catastrophe that seems inevitably attendant upon any real conflict at sea between the warships of our day. While we are at peace we can

look complacently at the enormous money stake thus set afloat in every iron-clad. We are amused by the newspaper accounts of the wonderful doings of a Devastation or some other terrible monster which, after a time, passes into oblivion, and as ten to fifteen millions must be annually spent upon the navy, we don't dwell much on the burden of these "fighting machines." But were the real blast of war to blow in our ears, and with worthy opponents such as may be discerned in the not distant future, the loss of ten or twenty of these costly monsters would simultaneously, or within a few months, command the attention of the nation in a very different way. No nation, not even one with the creative power and wealth of England, is rich enough to carry on a great war for any length of time upon a system which plays with half-million stakes upon the chances of a single cannon shot, and where the superiority won by courage, daring, and seamanship of former days is so much neutralized by mere mechanism, as is now the case, and must continue to be, while we continue the race of gun against plate. In the mean time it is one of the curious features of the case that science and invention have been hard at work upon methods of attack which, if successful, as some of them at least seem likely to be, must render absolutely nugatory all this ponderous armor as a means of defence and tremendous artillery for that of naval attack. With all the invulnerability of her sides, the bottom of the iron-clad is as defenceless against underwater explosion as is the belly of the poor crab against the tearing bill of the octopus. As a means of maritime defence the torpedo system has already proved itself powerful. The skilful barriers of moored torpedoes, by which Austria barred the entrance to Venice, were such as even British ships and crews would scarcely have dared to face, so certain and inevitable under almost all circumstances were these unseen means of destruction. At Pola, also, and in the American civil war, this means of defence proved correspondingly effective, but as a means of maritime *attack* the torpedo stands in a very different category. If we can only bring the explosive instrument into contact with the enemy's ship the result is pretty certain, but therein lies the difficulty; against the defensive torpedo, an enemy's ship or fleet must either keep aloof or run all the risks of a perhaps triple line of formidable and undiscoverable dangers; whilst as a means of attack there is added to the difficulties of directing a torpedo at all in any designed underwater transit, even against a fixed object, all those dodges and devices that vigilance and seamanship can suggest to enable the intended victim to evade the dreaded contact. We may here in passing direct the reader's attention to the critical and descriptive accounts to be found in our columns for the years 1867–68 of what had been achieved up to that period in the employment of torpedoes, both for defence and attack. The idea of an attacking torpedo is far from being a modern one. The "fire-ship" of Guianelli, the Italian engineer in the sixteenth century, of the city of Antwerp, was in reality a torpedo, which floated down with the tide and laid broadside on against the immense wooden bridge across the Scheldt, by which the Spaniards, under Parma, were steadily approaching the besieged city, was completely successful. Bushnell, an American engineer, very nearly succeeded in destroying a British frigate moored in American waters, by a torpedo brought to the ship and attached by the operator from his submarine boat, the torpedo being provided with a time lock.

About 1840, the well-known Captain Warner destroyed off Brighton a merchant ship placed at his disposal by what he called his invisible shell, which was in reality a torpedo drawn by a cord under the hull of the ship, and fired by the contact; but up to the advent of iron war shipping after the Crimean War little farther attention was given to this method of naval attack, the old system of cannonade, with the modern addition of firing live shells, which proved so tremendously destructive to the Turkish fleet at Sinope, proving more than sufficient for the destruction of any timber ship. Not long after the Crimean war a project was laid before our Admiralty for an attacking torpedo, consisting of a large shell suspended from the long bowsprit of the attacking ship, and so arranged that it could instantaneously be let go, and swing like a pendulum

against the quarter or side of an enemy's ship, on contact with which it exploded. A complete description of this early project exists in the archives of the Admiralty, and we shall probably be in a position at a future time to give its details and the name of the proposer. Several years afterwards very nearly the same idea was proposed to his own Government by the Russian Admiral Popoff, and is understood to have been adopted into that service. In this case, the pendulum shell was suspended from a derrick projecting to a considerable distance from the broad side of the ship, an arrangement in every respect inferior to the previous one, because it exposes the broadside of the attacking ship to the stroke of its own torpedo, with distance only to diminish the shock, in place of opposing to it her sharp bows, and also because a ship, discovered by the enemy's telescopes with the extraordinary appendage of a derrick projecting from her side, must create suspicion and be given a wide birth.

All such projects were at that period coldly received, and generally met with the request that they should remain in the Admiralty archives, and not be publicly mooted until a more convenient season. Since that time, and especially during the last ten years, a great deal of attention has been directed, though in a way so unobtrusive as to escape much public notice, by our naval and military authorities to experiments, upon the various contrivances brought to its notice by officers of either service, as well as by outside inventors. Amongst these, both in America and in England, were various projects for firing torpedoes, either from a large vessel like the Spuyten Duyvel, provided with an underwater tunnel, from out of which the torpedo was thrust, or by a torpedo fixed at the end of a boom or underwater bowsprit, carried by some description of small craft, and fired by contact, but neither of these projects could be feasibly applicable, except under very exceptional conditions, and thus the great problem remained open of some effective method of directing from a distance a torpedo which should come into contact with the hull of an enemy's ship and there explode. Among the more noticeable of these have been Harvey's torpedo, which floated forth from the attacking vessel at a known depth from the surface, is sent down upon the vessel to be attacked, whether by current or by its contained power, direction being given to it by its peculiar trapezoidal horizontal section, and by means of directing guy cords or wires. Whatever favorable results may have been stated to have been obtained with this machine, it is obvious that the means of direction must prove wholly ineffective if the distance between the ships be great, and any transverse current or wave action has to be encountered. The means of propulsion contained within the body of a torpedo is, like those for its direction, a matter of much difficulty. The relative density of the torpedo must be unaltered during its transit, for it must not alter its level beneath the surface of the water. Two concentric screw propellers, revolving in reverse directions, and actuated from within by compressed carbonic acid, or some other elastic vapor or gas, or by coiled-up metallic springs, or by electro-motive power, generated within the torpedo or in the attacking ship, and transmitted through an insulated wire, as in Way's, and one or more American inventions, have been among the mose promising methods of propulsion employed, but in all these the rate of transit through the water is not great, and the less that is, the less certain becomes the aim that can be taken at the ship to be struck.

Within the last year or two, experiments have been conducted at Woolwich upon a form of torpedo, the invention of Mr. Whitehead, an English engineer, for some time employed by the Austrians in experimenting upon torpedoes at the naval port of Pola, on the Adriatic. Mr. Whitehead's torpedo, with self-contained propulsive power, is stated to have been, in the judgment of the Austrian authorities, so successful as to have received a reward of £15,000. His invention was subsequently communicated by himself to our Government, and its merits sufficiently recognized—if we be rightly informed—by a large payment made to the inventor. It is also said to have been purchased by the American as well as by the French Government for large sums; so that Mr. Whitehead has already received a very ample reward for his invention. His torpedo consists of an

elongated metallic vessel, provided with projecting flanges or fins intended for securing its direction of motion only, the explosive agent being contained at the forward end, while the after end incloses a cavity into which air is compressed to a very high pressure (100 or more atmospheres), which thus requires a vessel of great thickness and strength. Much secrecy has been observed with respect to what is contained besides within the torpedo. The compressed air, however, is caused to act upon a double or concentric pair of right and left screw propellers by means of a little pair of air-engines; the torpedo is also provided with a rudder, which may be set to various angles so as to counteract lateral drift way, and it is stated or surmised that the obliquity of this rudder may be automatically altered in the event of the transverse current or other divellent force altering during the transit. This torpedo has been reported on by an American experimental commission, excerpts from which report will be found in *The Engineer*, vol. xxxvii., page 141. The enormous air pressures necessarily employed in this torpedo for even very moderate distances of transit form a great objection to its use, and already the experimental trials of it in this country have been attended with fatal results. Notwithstanding which, the rate of propulsion attained up to a very recent period does not appear to have reached more than about ten miles an hour, although, if the reports which have reached us be quite reliable, a speed largely exceeding this has been obtained at Woolwich in trials made in the Arsenal canal, in which a straight reach of considerable length exists. The greatest experimental distance of transit which limits the distance between the attacking and attacked ships does not as yet appear to have exceeded about 600ft., although the torpedo let loose in the water is capable of making a transit of about four-fifths of a mile, but no doubt with great uncertainty as to direction and reduction in speed.

If a velocity, as said to have been attained at Woolwich, approaching 30ft. per second, or even one a good deal less than that, has actually been attained, the submarine torpedo promises to become a really effective weapon of attack. Most of the experiments hitherto made with this class of torpedoes have been conducted at distances not exceeding 300 yards between the attacking and attacked ships, it being assumed that at that distance the attacking ship would be comparatively safe from the artillery of her opponent, the accuracy of aim decreasing rapidly with the distance through the movements of both ships, the smallness of the mark presented, and deviations in flight. Now, at the above rate, 300 yards of water would be run through in less than two minutes, and bearing in mind that every deviating force upon the torpedo due to wave or current action, and every disturbing influence arising from the movements of both ships, must be produced in proportion as the velocity of torpedo transit is greater, it would seem probable that here at length a reasonable chance is presented for striking the enemy's hull, and thus one prime difficulty of torpedo attack be overcome, though many others still remain to be surmounted. We are enabled to state, however, that in 1861–2, Mr. Charles Lancaster presented to our War Department designs and description for a torpedo which, like Whitehead's, contained its own means of propulsion. These designs were received and acknowledged with the request that they should be allowed by the inventor to repose in the archives of the War Department until some future necessity might arise for the employment of such a destructive mode of warfare, and so the matter did rest until a comparatively recent period, when, having heard of Mr. Whitehead's success, Mr. Lancaster called the attention of the authorities to his anticipation of the invention in 1861–62, or twelve or thirteen years since. From the nature of Mr. Lancaster's propulsive agent, a transit velocity equal at least to anything said so far to have been attained by Whitehead's and one that might be made greatly to exceed that of the latter, is physically possible, and would be attended with no danger to the operators. The torpedo itself might be much lighter, simpler, and less expensive both in construction and use, and if the splendid reward of £10,000 has been paid to Whitehead, it seems but hard lines that Lancaster should not be rewarded for his invention, which has been in the

hands of Government for twelve or thirteen years, and which offers some positive advantages over Whitehead's invention. There are two vulnerable places in every ironclad as yet constructed—the bottom and the deck—and whether the problem of attack by torpedo, and whether by Lancastre or by Whiting, be already solved, or on the way to solution, the attack by the vulnerable deck, remains an almost untouched subject for the inventive skill of the naval artillerist. A single very large shell lobbed in upon the upper deck and there exploded, would almost certainly put any ironclad *hors de combat*.

It was proved at Woolwich Marshes that a charge of only 10 lb. of powder sent a 36in. shell, weighing above a ton, a horizontal range of 360 yards, while with 20 lb. charge the range was increased to more than 900 yards, and with such small charges such shells might be fired from a mortar or howitzer weighing far less than an 18-ton gun. Probably spherical shells would not be the best for remaining where lodged upon a deck until the explosion took place, but the whole subject presents an excellent field for investigation, for the possibility of lodging a large shell, whether spherical or of some other form, upon an enemy's deck at such very short ranges can scarcely admit of debate, and if a ship of war may venture to approach another within 300 yards for the purpose of discharging a somewhat uncertain underwater torpedo, she may unquestionably do the same for the purpose of landing upon her opponent's deck a destructive shell, even though the latter be still subject to the possibility of missing its mark. Under circumstances otherwise alike, the attacking ship thus employed would have one element of safety which is scarcely possible if the attack be made by torpedo. The torpedo ship must arrest her course and become stationary before she can with any certainty launch her weapon; the mortar ship, on the contrary, may keep on her way without her motion deranging sensibly that of the shell fired in the direction of her bows during its very short flight.

THE MARINE ENGINE OF TO-DAY.

From "Naval Science."

The more rapid decay of the boiler which has attended the comparatively slight increase of the pressure of the steam in the marine engine during the past few years presents a problem to the solution of which much attention is being paid, and probably, ere long, means will be found to remedy an evil which goes far to neutralize the gain in economy of fuel due tothe use of high-pressure steam. The mechanical difficulties to be met in the construction of a sectional marine boiler for extreme pressures appear already to have been, in a great measure, overcome, and no doubt perfectly trustworthy boilers of this kind can be made which will generate steam as efficiently as the boilers now in use, but advances in the direction of higher pressures must necessarily be slow in the case of the more important sea-going ships. Sufficient experience has, however, been gained with steam of from 60 to 80 lbs. pressure to enable the boilers now ordinarily in use at sea to be kept in fair order under the conditions to which they are subject in the majority of sea-going commercial ships, and for some time to come this must be regarded as the working pressure of ocean steamers.

The compound type of engine in general use at this pressure at the present time in the merchant service of this country, and adopted for the Royal Navy within the past few years, is one which, while possessing some evident advantages, also possesses serious defects; and notwithstanding the risks which attend the trial of novel machinery on shipboard, attempts have been made on a considerable scale in the commercial marine to introduce simple expansive engines. With the exception of the North German Lloyd's Co., the steamship companies on this side of the Atlantic who have tried machinery of this kind do not appear to have met with any measure of

success, but in numbers of American steamers the simple expansive engine is used with most satisfactory results, and in a form which, to many English marine engineers, appears to be the most objectionable, a single cylinder and crank only being used. The relative merits of the two types of engine have formed the subject of much discussion in the technical press, and among the various engineering societies. We have ourselves devoted some space to the consideration of the subject, especially with reference to the use of the rival engines in ships-of-war, and the conclusions we arrived at were not favorable to the compound engine. The greater difficulty of rapidly handling, and the much greater liability to disablement, of this form of engine, its greater complication, and the larger space occupied by it in the ship as compared to the simple engine, renders its use in fighting ships specially objectionable. The objections to it in these respects apply in a minor degree to its application to commercial steamers, but they are sufficiently grave to warrant the use of the rival engine in many cases, even at a possible sacrifice in point of economy of fuel. What sacrifice would result, or whether any loss at all would occur, in the large engines of ocean steamers, is a matter upon which no absolutely decisive evidence at present exists, but, making use of such data as recent experience furnishes, we will endeavor in the present article to place the matter in such a form as to enable our engineering readers to arrive at a conclusion as to what are the probabilities in this respect.

The advisability has been suggested of introducing some more trustworthy system of trial, and proposed, for these runs, the registration of the weight of condensed steam discharged from the surface-condensers and jackets with the object of determining the efficiency of the steam in the engine. A trial of an engine of the compound marine type was made at Chatham Dockyard, last July, in this way. The particulars of this trial, which are of considerable interest, have just been published in the Prize Essay of the Junior Naval Professional Association,* together with the results of an important series of experiments recently made in the same way in America. For full particulars of these experiments and analyses of the results we must refer our readers to the Essay, confining ourselves to using the figures given so far only as they bear upon the points to which we wish to direct special attention.

When examined before the Committee on Admiralty Designs, in the early part of 1871, Mr. Reed strongly expressed an opinion that the economy stated to be due to the compound form of engine had been greatly exaggerated, and the evidence now accumulating confirms the opinion formed upon the imperfect data available at that time. Figures like 1.3 or 1.5 lbs. of fuel per indicated horse-power per hour have been constantly quoted for compound engines working at sea at pressures varying from 60 lbs. to 90 lbs. absolute at the outside, and, as engineers who have really studied the question are aware, a combination of the most impossibly favorable circumstances is required in order to attain such a result.

In the first place, the quantity of heat available for the performance of useful work in a steam engine is such that, in a condensing engine supplied with steam from an ordinary marine boiler evaporating 8 lbs. of water per lb. of fuel, the coal used could not be less than 1.15 lbs. per indicated horse-power per hour at 60 lbs. pressure absolute, presuming that all the ordinary causes of loss were eliminated. In order to obtain this result, losses from radiation, leakage, clearances, induced liquefaction, due to causes other than the performance of work during expansion, would require to be got rid of, and the expansion would have to be carried out to the lower limit of temperature, that of the condenser, taken in this case at 100° Fahrenheit. Under these circumstances the weight of steam theoretically required for pressures up to 120 lbs. absolute, as given by Professor Cotterill in his "Notes on the Theory of the Steam Engine," is as follows :

* "The Relative Merits of Simple and Compound Engines as Applied to Ships of War." Prize Essay. By Niel McDougall, Assoc. I. C. E., M. I. N. A., of the Department of the Controller of the Navy. (Griffin & Co., 15 Cockspur Street, Pall Mall, London, and 2 The Hard, Portsea, Portsmouth,)

Pressure in atmospheres.	No. of lbs. of steam required per horse-power per hour.
2	11.2
4	9.2
6	8.3
8	7.7

The accuracy of these figures can readily be demonstrated from the known properties of saturated steam, but the weight of steam actually required per H. P. for any given engine is a matter upon which but little trustworthy information is available. It is necessarily much in excess of the theoretical weight, bearing no definite relation to it. As a check upon the unhealthy spirit of emulation in the production of remarkable figures which the demand for economy of fuel has engendered, it is well, however, to keep the theoretical figures in view in considering the probable accuracy of results stated to have been obtained in actual practice.

It is to the loss from condensation in the cylinder that the difference between the theoretical and the actual weight of steam used expansively is in most engines chiefly due, and it is to the prevention of the losses from this source that improvement in the steam engine has been for some time in a great measure directed, although no definite knowledge of the extent of the loss traceable to condensation in the modern engine has existed. That it is actually greater, and that its effectual prevention in practice is more difficult than has been supposed by eminent authorities, appears to be evident from the most recent experiments. Professor Rankine appears to have regarded its prevention as a matter of no great difficulty, and to have considered that the extent to which expansion could be carried with useful effect should be determined from the back pressure in the cylinder and the resistance due to the friction of the engine, the terminal forward pressure of the steam for maximum efficiency being just sufficient to balance these two. In a paper on the "Economy of Power in Compound Marine Engines," submitted to the Committee on Admiralty Designs, he states:

"It is obvious that work continues to be done by the steam in driving the piston so long as the pressure behind the piston, or forward pressure, continues to be greater than the pressure in front, or back pressure, exerted by the steam which has already done its work, and which the piston is expelling from the cylinder; and hence it follows that in order to realize the greatest quantity of work which the steam is capable of performing the expansion ought to be carried on until the forward pressure of the steam behind the piston has fallen so low as to be just sufficient to overcome the back pressure; and that to end the expansive working of the steam at an earlier period of the stroke is to throw away part of the power of the steam.

"This statement must, however, be taken with the qualification that when the excess of the forward pressure above the back pressure falls below the pressure which is just sufficient to overcome the friction, the work done is no longer partly useful and partly wasteful, but is wholly wasteful; whence it follows that although, in order to obtain the greatest *indicated* work from a given weight of steam, the expansion should be continued until the forward pressure becomes just equal to the back pressure, the greatest *useful* work is obtained by making the expansion cease when the forward pressure is just equal to the back pressure added to a pressure equivalent to the friction of the engine."

And further:

"In order to realize the theoretical greatest efficiency in the expansive working of steam, the expansion ought to take place in a non-conducting cylinder, with a non-conducting piston. This condition cannot be absolutely realized in practice; but means may be taken to diminish the loss of efficiency arising from the conducting power of the cylinder and piston until they become unimportant."

For the proportions of cylinder usual in compound marine engines the pressure per square inch required to overcome the friction in engines of good construction is such that the friction diagrams at the speeds at which they are usually taken become a mere line, and for all practical purposes the size of the low pressure cylinder might be determined on the supposition that the forward terminal pressure would correspond with the or-

dinary back pressure if the maximum efficiency of the steam were to be attained in the manner indicated by Professor Rankine. It appears to be evident, however, that the losses from the clearances and condensation at the higher grades of expansion affect the performance of the engine so seriously that the maximum efficiency of the steam is reached at a rate of expansion which places the terminal forward pressure much above that of the combined resistance of friction and back pressure, as will be plainly seen from the American experiments quoted further on. This remark applies to engines of both the compound and simple types, and before discussing the relative economy of the two kinds of engine it will help to form a just estimate if, in the first place, some idea can be given of the value to be attached to the remarkably good results in point of economy so frequently claimed for the compound engines now in ordinary use at sea.

The results of the trial at Chatham Dockyard, published in the Prize Essay of the Junior Naval Professional Association, are of considerable interest, as the engines are of the same type, but placed vertically, as those of the now well-known 'Briton' class. The engines are by the same makers as those of this ship, and are jacketed in the same way, the low pressure cylinder only being jacketed. The trial is the only one of a large compound engine of the marine type conducted in this country with which we are acquainted in which provision has been made to determine the efficiency of the engine apart from that of the boiler, and we here reprint the principal particulars, as they are also of special interest on this account :

TRIAL OF DOCK PUMPING-ENGINES H. M. DOCKYARD, CHATHAM, JULY 13TH, 1874.

Diameter of Cylinders	H. P. 43 ins., L. P. 75 ins.
Length of stroke	2 ft. 9 ins.
Mean pressure of steam in the boilers	53.5 lbs. per square inch.
Mean number of revolutions per minute*	87.6.
Mean pressure in cylinders	High 23.784, Low 5.993.
Indicated horse-power	High 505, Low 387—Total 892.
Duration of trial	3 hours 32¼ minutes.
Description of coal used	Fothergill's Aberdare.
Quantity of coal used	12,320 lbs.
Quantity of coal used per I. H. P. per hour	3.74 lbs.
Water collected from hot-well	60,228 lbs.
Water collected from hot-well per I. H. P. per hour	18.42 lbs.
Water collected from steam-jacket	1,312 lbs.
Water collected from steam-jacket per I. H. P. per hour	0.401 lbs.
Water collected from steam-pipes	315 lbs.
Total quantity of water per I. H. P. per hour	18.922 lbs.
Quantity of coal burnt per square foot of fire-grate	17.8 lbs. per hour.
Velocity of piston, feet per minute	481.8.
Volume swept by piston per I.H.P. per minute, L.P. cylinder	16.57 cubic feet.
Volume swept by pistons per I. H. P. per minute....Total...	22.03 cubic feet.

It is remarked in the Essay with regard to the results :

"It will be seen that the consumption of fuel determined in the same way as on the six hours' runs was found to be 3.74 lbs. per I. H. P. per hour. On a previous trial of 1¾ hours' duration, as a check upon which the present trial was ordered, the consumption of fuel had been calculated at 3.42 lbs. The steam is supplied from ordinary double-flued mill boilers, and upon subsequent evaporation trials of one of the boilers at atmospheric pressure it was found that the weight of water evaporated per lb. of fuel from 100° was 9.103 lbs. when burning 17.53 lbs. of fuel per square foot of grate per hour, the estimated rate of combustion, as will be seen above, on the trial, having been 17.8 lbs.

"As will also be seen, the total weight of steam or water, as measured, was 18.92 lbs. per I. H. P. per hour. This would give only 5.59 lbs. of water evaporated per lb. of fuel by the boiler, the lowest evaporative trial of which at atmospheric pressure gave 7.843 lbs. The coal used on all the trials was of first-

* The engines drive large centrifugal pumps, and the revolutions varied with the height of lift.

rate quality, and its evaporative power when tried in the marine test-boiler was found to be 9.635 lbs. of water from 100° per lb. of fuel.

"There are two things which are probable here—first, that the coal per H. P. as calculated is too high; and second, that the weight of steam per H. P., as measured, is too low. It would be impossible to fix accurately the weight of steam and fuel actually used, but making the liberal allowance of one-fourth, or 25 per cent., for error, we have 2.82 lbs. of coal per I. H. P. per hour as the probable consumption for an engine of the 'Briton' type, driven by ordinary Lancashire boilers, using the best Welsh coal, the probable rate of combustion being then only 13.35 lbs. per square foot of grate per hour, and if we assume that 8 lbs. of water were evaporated by the boiler per lb. of fuel, we have 22.56 lbs. of steam per I. H. P. per hour used by the engine."

These figures certainly form a remarkable contrast to the results of the lower power trials of the early high presssure compound engines tried in the Navy, and to the figures constantly given for the compound engines of the merchant service. An ordinary Cornish or Lancashire boiler at so low a rate of combustion as 13.35 lbs. of coal per square foot of grate might be expected to be nearly, if not quite, as economical as a cylindrical marine tubular boiler burning 20 lbs. per square foot of grate at sea. Looking, therefore, at the probable result of 2.82 lbs. of the Chatham trial, and keeping the theoretical consumption of 1.15 lbs. of fuel per H. P. in view, the value to be attached to such figures as 1.3 lbs. or 1.5 lbs., given for engines working as a rule with steam of about 45 lbs. or 50 lbs. supplied from boilers burning coal certainly not superior to Fothergill's Aberdare, may be judged of. Although, apparently, figures like these have been widely accepted as trustworthy, we have by no means been alone in expressing our doubts as to their accuracy. In a most interesting report by a board of American engineers to the Secretary of the United States Navy, published in 1874, the gain in economy by the use of the compound engine with 60 lbs. pressure, as compared to the simple engine of that Navy worked at 30 lbs. pressure, is calculated at 29.26 per cent., the weight of steam per horse power for the compound engine being determined as 22.46 lbs. The report states:

"The gain of 29.26 per centum in the cost of the indicated power is much less than that usually claimed for the compound engines by persons interested in their manufacture. If, as is often asserted, the indicated horse power is obtained at a cost of only two pounds of coal per hour, the boilers employed must evaporate 11.23 pounds of water per pound of coal. This quantity is much greater than has ever been evaporated by boilers of the types employed with the compound engines under consideration. The quantity of water evaporated in such boilers per pound of coal, at the high rates of combustion generally employed in English practice, will be found not to exceed eight pounds of water from a temperature of 100° Fahrenheit. When the apparent evaporation is greater the increase may be due to superheating the steam, the results of which practice may be equally advantageous in the case of engines of either type. The cost of the indicated horse power, then, in lbs. of coal per hour would be $\frac{22.46}{8} = 2.81$."

The coal trials conducted in the Royal Dockyards furnish ample evidence that the evaporation of 8 lbs. of water per pound of coal is a very good performance for a marine boiler under ordinary working conditions at sea, while from the recent American trials it appears to be probable that expansion is carried to too great an extent for economy in the generality of compound engines of English design. The best result given by the compound engine in these trials was attained by the 'Rush' with a ratio of expansion of 6.2, the volume swept by the piston of the low pressure cylinder being only 9.42 cubic feet per horse power per minute. The cylinders in this case were completely jacketed, and with a boiler evaporating 8 lbs. of water per pound of coal the consumption of fuel per H. P. per hour would be 2.3 lbs. The engine, as will be seen further on, was of small size, but a comparison of the result with that

of the Chatham engines is instructive, and, taken in conjunction with the result of the 'Bache' trials, it tends to show that the capacity of cylinder in engines of English design is unnecessarily large.

For engines of large size the figures given for the Admiralty six hours' runs are probably the most trustworthy yet available, as the coal used on all occasions is of practically the same quality from the best Welsh beds. Referring to the table below, it will be seen that the four last trials of the compound engines do not differ materially, and a mean of the five trials gives 2.4 lbs. of the best Welsh coal used per horse power per hour. This is below the probable result of the Chatham trial, but comparing it with the results given by five simple low pressure engines a gain of 18 per cent. by the use of the compound high pressure engine is shown. To obtain this result the capacity of the cylinder has been increased 50 per cent., and the pressure above the atmosphere has been doubled. The trials are all at full power, but it is pretty evident from the American experiments that the maximum expansion for economy had been reached in the compound engines, and that at lower power any further economy would simply be due to increased efficiency of the boiler.

	Name of Vessel.	When tried.	Steam pressure; lbs. per sq. in. above atmosphere.	I. H. P.	Volume swept per I. H. P. per min. by piston.		Coal used per I. H. P. per hour.
					Cubic feet.		lbs.
Single engines.	Monarch	1869	25 lbs. to 30 lbs.	7470	11.8		2.79
	*Devastation	1873		5652	11.64		2.928
	Hercules	1869		7187	12.5		2.811
	Sultan	1871		8778	11.19		3.109
	Druid	1871		2038	12.6		3.001
					L. P. cylinder.	Total.	
Compound engines.	Briton	1870	55 lbs. to 60 lbs.	2019	13.4	17.8	1.981
	Thetis	1872		2036	13.6	18.0	2.545
	Thetis	1873		2000	—	—	2.600
	Amethyst	1873		1990	14.7	19.6	2.463
	Encounter	1873		2030	14.5	19.4	2.425

There can be no doubt that in some minds the belief in the efficacy of passing steam through a succession of cylinders amounts to little short of a superstition, and in such cases the important inferences to be drawn from figures like those given above are lost sight of. The fact is overlooked or forgotten that it was not until the compound engine was worked at higher pressure than the engines it has superseded that its superior economy could be distinguished at sea; that on land low pressure compound engines have been superseded wholesale by high pressure simple expansive engines; that there is abundant evidence that an increase in the pressure of the steam is followed by increased economy in the simple as in the compound engine, and that, therefore, on the broadest possible grounds, it might be expected that with equal steam pressure the difference between the performance of the two engines, as shown above, would be largely reduced, if it did not entirely disappear.

The experiments with the engines of the 'Dexter' furnish direct evidence of the economy which results from the use of higher steam pressure in the simple engine. Taking trials Nos. 3 and 7 for comparison, it will be seen below that in the same engine the horse power cost 20¾ per cent. more at 40 lbs. pressure than at 70:

* Twin Screws.

No. of trial	3	7
Mean boiler pressure above atmosphere lbs.	68.70	40.625
Indicated H. P.	185.872	124.267
Weight of water used per I. H. P. lbs.	23.8572	28.802
Ratio of expansion	4.557	3.337

This was in a completely clothed but unjacketed cylinder.

The very different results which may be obtained from steam of the same pressure in different engines of the same type is very clearly shown by comparing the results of the trial of the American steamer 'Mackinaw' (tried by Mr. Isherwood in 1864) with those given by the engines of the 'Dallas,' recently tried.

'MACKINAW.' SATURATED STEAM.

Diameter of cylinder	58 ins.
Length of stroke	8 ft. 9 in.
Clearances / Effective capacity of cylinder	0.84

Ratio of expansion	1.38	1.68	2.33	3.68
Cut-off	.70	.56	.38	.21
Boiler pressure above atmosphere lbs.	27	28	35	38
Absolute initial pressure in cylinder lbs.	41.32	43.0	49.0	53.0
Feed water used per I.H.P. per hour lbs.	32.913	30.628	30.31	36.04
Proportion of feed water accounted for by the indicator	.9254	.8857	.7818	.6218
Revolutions per minute	67.79	68.69	66.28	56.09

'DALLAS.' SATURATED STEAM.

Diameter of cylinder	36 inches.
Length of stroke	30 inches.
Clearances / Effective capacity of cylinder	0.0802.

Ratio of expansion	2.317	2.935	3.893	5.067
Cut-off	.385	.287	.197	.132
Boiler pressure above atmosphere lbs.	27.4	33.7	35.28	35.40
Absolute initial pressure in cylinder lbs.	39.43	45.86	47.04	46.90
Feed water used per I. H. P. per hour lbs.	30.99	28.90	26.96	26.68
Proportion of feed water accounted for by the indicator	.7348	.7337	.7687	.7195
No. of revolutions per minute	63.46	64.48	56.92	48.68

The ratio of clearances to effective capacity of cylinder was practically the same in the two cases, and under like conditions in other respects the larger engine might be expected to be the more economical. That the loss in the 'Mackinaw' was directly due to liquefaction is evident from the fact that the proportion of steam accounted for by the indicator gradually decreased at the higher grades of expansion, the proportion liquefied in the 'Dallas' remaining practically constant at all grades. It was also found in the 'Mackinaw' that on superheating the steam to such an extent that the indicator showed approximately the same weight of steam as actually used (the weight being calculated from the diagrams on the assumption that the volume indicated was that of saturated steam), the steam used per indicated H. P. fell considerably below that required for the 'Dallas,' using saturated steam, the figures being as under:

'MACKINAW.' SUPERHEATED STEAM.

Cast-off	.65	.23
Boiler pressure above atmosphere.....lbs.	38	39
Absolute initial pressure in cylinder.....lbs.	43.97	52.0
Feed water used per I. H. P. per hour.....lbs.	24.59	22.725

The cylinder of the 'Mackinaw,' like those of the other engines tried by Mr. Isherwood, was unjacketed and only partially covered with felt, the ends and slide-casing being unprotected. The cylinder of the 'Dallas,' on the other hand, was thoroughly protected, but the superior economy of this engine with saturated steam must have been mainly due to its greater speed. Although on account of its smaller size two square feet of condensing surface were presented in the cylinder of the 'Dallas' for every cubic foot of steam room, against one square foot in the 'Mackinaw," yet the time occupied in making a stroke was only one-ninth of that taken by the piston of the larger engine. In the absence of information as to the relative dryness of the steam used in the two engines, it is of course impossible to attach an exact value to the influence of the greater speed in presenting liquefaction, but the trials of these two ships may fairly be taken as showing the importance of high speed as an element of economy at the higher grades of expansion in unjacketed cylinders.

Whether the speed of the piston can be increased to such an extent in practice as to render the jacket superfluous is a question upon which it is impossible to speak with any degree of certainty. Judging from experience with the locomotive, using steam almost invariably super-saturated, it appears to be possible that this is the case. With saturated steam used expansively at ordinary speeds of piston, however, the jacket is essential to economy, and the recent American experiments show this plainly, although they also appear to show that its influence is not sufficient to admit of expansion being carried out to any great extent with adequate gain in economy.

Tabulated in Table 1 are leading particulars of some of the recent trials, and in Figs. 1 and 2 are shown diagrams from the engines of the 'Rush.' The great difference between the results

Fig. 1.—U. S. REVENUE STEAMER 'RUSH.' HIGH-PRESSURE CYLINDER.
Scale of indicator, 40 lbs. per inch.

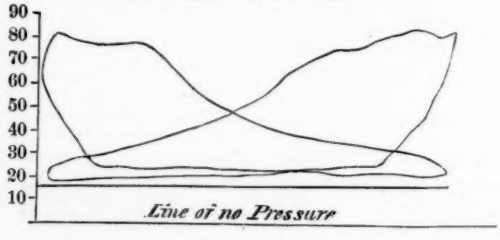


Fig. 2.—LOW-PRESSURE CYLINDER.
Scale of indicator, 16 lbs. per inch.

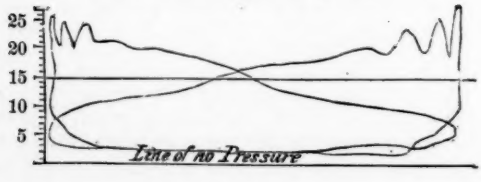


TABLE No. 1.

	Jacketed Cylinders.		Unjacketed Cylinders.		
	Rush compound engine.		High pressure.		Low pres.
	High Pressure.	Low Pressure.	Bach compound engine.	Dexter simple engine.	Dallas simple engine.
Number of trials for reference	1	2	2	5	12
Diameter of cylinder { High—ins.	24	24	15.98	26	36
Diameter of cylinder { Low —ins.	38	38	25		
Stroke of pistons...ins.	27	27	24	36	30
Date of trial	Aug. 1874	Aug. 1874	May 1874	Aug. 1874	Aug. 1874
Duration of trial...hours	55	6	2.06	34.5	31
Mean steam pressure in boiler...lbs.	69.06	36.73	80.28	67.12	31.96
Ratio of expansion	6.21	4.03	6.65	3.48	3.13
Mean vacuum in condenser...ins.	26.49	26.21	24.32	25.45	25.20
Mean number of revolutions per min.	70.84	55.47	47.69	61.06	61.51
Initial pressure in cylinder above atmosphere { H. P.	67.46	35.44	76.33	64.40	31.85
Initial pressure in cylinder above atmosphere { L. P.	8.65	7.18	2.45		
Absolute initial pressure in cylinder { H. P.	82.27	50.24	91.05	79.20	46.58
Absolute initial pressure in cylinder { L. P.	23.46	21.98	17.15		
Mean effective pressure...lbs. { H. P.	29.68	18.88	43.51	37.53	23.52
Mean effective pressure...lbs. { L. P.	12.72	12.29	9.75		
Estimated friction pressure...lbs. { H. P.	2.5	2.5	0.75	3.0	2.5
Estimated friction pressure...lbs. { L. P.	1.5	1.5	2.25		
Indicated horse-power	266.54	168.65	77.06	218.97	221.44
Effective horse-power	239.43	145.17	69.81	201.47	197.91
Steam per I. H. P. per hour...lbs.	18.383	22.094	23.036	23.905	26.94
Steam per effective H.P. per hr..lbs.	20.46	25.66	25.427	25.98	30.14
Coal per I.H.P. per hour... { Calculated for evaporation of nine lbs. water per lb. of fuel. } lbs	2.042	2.455	2.559	2.656	2.993
Coal per effective H. P. per hour... { Calculated for evaporation of nine lbs. water per lb. of fuel. } lbs	2.273	2.851	2.825	2.886	3.349
Ratio of L. P. to H. P. cylinder capacity	2.25	2.25	2.5	—	—
Effective capacity of cylinder, cubic ft. per I. H. P. per minute... { H. P.	3.76	4.65	3.46	6.17	9.81
Effective capacity of cylinder, cubic ft. per I. H. P. per minute... { L. P.	9.42	11.65	8.44		
Velocity of piston per minute...ft.	318.8	249.6	190.8	366.4	307.5

given by the jacketed and unjacketed compound engine will at once be seen, the unjacketed engine of the 'Bache' using as much steam per H. P. at 80 lbs. pressure as that of the completely jacketed engine of the 'Rush' at 37 lbs. How much of this difference was directly due to the jacket in this case is not evident, however. In Table 2 it will be seen that the compound engine of the 'Bache' was not so economical as that of the 'Rush,' even when using the jacket, and Mr. Emery suggests as an explanation, in his analysis of the experiments, that from the form of boiler the steam used in the cylinders of the 'Rush' might have been slightly superheated. The smaller size of cylinders, lower speed, and the fact that the large cylinder only was jacketed in the 'Bache,' all, probably, tended to a less economical result. Judging from the evidence of the indicator diagram, so far as it can be trusted, this type of compound engine, having one cylinder above the other, could hardly be expected in any case to be quite as economical as that of the 'Rush,' having two cylinders side by side with cranks at right angles. The most direct evidence of the utility of the jacket is, however, given by the trials of the 'Bache,' and here it will be found from trials No. 13 and 16 (Table 2) that the gain in the simple engine by the use

TABLE NO. 2.

Bache.

	Compound Jacketed.			Simple not Jacketed.	Simple Jacketed.	Compound not Jacketed
Number of trial for reference.....	7	8	9	13	16	3
Diameter of cylinder { High—ins..	15.98	15.98	15.98	25	25	15.98
Diameter of cylinder { Low —ins..	25	25	25			25
Stroke of pistons.....ins..	24	24	24	24	24	24
Date of trial.....	May 12, 1874	May 14, 1874	May 15, 1874	May 18, 1874	May 18, 1874	May 14, 1874
Duration of trials.....hours.	1.983	7.066	15.233	2.05	2.116	2.133
Mean steam-pressure in boilers. lbs.	80.12	79.96	79.77	78.11	79.5	80.31
Ratio of expansion.....	5.732	5.707	5.097	5.32	5.11	5.634
Mean vacuum in condenser....ins.	26.56	26.11	24.39	24.22	25.52	24.656
Mean No. of revolutions per min..	56.34	55.29	53.62	47.07	53.84	49.265
Initial pressure in cylinder above atmosphere	75.41	H. P. 75.32	74.47	72.75	76.1	73.00
	8.66	L. P. 8.96	7.52			3.9
Absolute initial pressure in cylinder.....	90.30	H. P. 90.04	88.78	87.39	90.74	87.72
	23.55	L. P. 23.68	22.83			18.62
Mean effective pressure.....lbs.	42.93	H. P. 45.37	43.06	32.328	36.94	45.137
	15.88	L. P. 13.96	14.908			11.2756
Estimated friction pressure..lbs.	0.75	H. P. 0.75	0.75	2.25	2.25	0.75
	2.25	L. P. 2.25	2.25			2.25
Indicated horse-power.....	110.51	106.028	102.263	89.1	116	85.81
Effective horse-power.....	102.06	97.7	94.2	82.9	109.37	78.447
Steam per I. H. P. per hour....lbs.	20.3648	21.9661	22.3798	26.247	23.154	23.21
Steam per effective H.P. per hr. lbs.	21.9989	23.8385	24.287	28.21	24.56	25.3887
Coal per I.H.P. per hour ... Calculated for evaporation of 9 lbs. water per lb. of fuel..... lbs.	2.263	2.441	2.487	2.917	2.573	2.579
Coal per effective H.P. per hour..... lbs.	2.444	2.649	2.699	3.134	2.729	2.821
Effective capacity of cylinder, cubic ft. per I. H. P. per min.. {	2.8	H. P. 2.9	2.9	7.2	6.3	3.0199
	6.9	L. P. 7.1	7.1			7.811
Velocity of piston per minute.....	225	222	214	188	215	197

of the jacket amounted to 11¾ per cent., the gain in the compound engine not being so much as this in the trials, the results of which are given in Table 2. But a comparison of other trials of the same compound engine (trials Nos. 2 and 6) shows the same gain as in the simple engine.

That increased economy is obtained by the use of steam of higher pressure in the simple engine is obvious, and the utility of the jacket, superheating, and high speed, as means of preventing loss from condensation, is also evident. The question, then, is, first, to which of the rival types of engine are these means of preventing waste most applicable in practice, and second, whether the compound engine when used under the conditions which experience has shown to be necessary for its satisfactory working is likely to be superior in economy at present pressures to the simple engine designed in accordance with the lessons which the limited experience with it have taught.

At pressure of 60 lbs. to 80 lbs. per square inch experience has shown that the superheater cannot be used with any degree of safety for the compound engine on account of the scoring of the cylinders and valve faces due to the high temperature and dryness of the steam. In the simple engine the lower mean temperature of the cylinder, as compared with the high pressure cylinder of the compound engine, would enable the superheater to be used with somewhat greater safety, but the valve faces would suffer in the same way in both cases, and, so far as we are aware, the superheater has not been used in any case with the

high pressure simple expansive engine at sea. With boilers having sufficient steam room to insure approximately dry saturated steam being supplied to the engine, it appears to be decidedly better to use the jacket in preference to the superheater in either type of engine. Here we find that in the compound engine with the high temperature maintained in the high pressure cylinder the use of the jacket on this cylinder has so frequently led to rapid wear, that in the practice of many engineers it has been abandoned on this account, and its use, where fitted, has been largely abandoned at sea. In some of the most successful compound engines the jacket on the low pressure cylinder has also been dispensed with, not, however, in this case on account of wear, but for the sake of simplicity, it being considered that any gain in economy which might be due to the jacket is not snfficient to counterbalance the additional cost and complication involved in the construction of an already sufficiently complex engine. It may be noted also that some of the experiments with the 'Bache' appear to bear out the supposition that with the steam but slightly expanded in each cylinder the use of the low pressure cylinder jacket is not attended by any marked advantage in engines of this type.

With the greater range of temperature of the cylinder of the simple engine, the effect of the jacket in inducing rapid wear could not be expected to be so great as in the high pressure cylinder of the compound engine, and there is nothing to show that any ill effects traceable to its use have been found at sea.

So little is known as to the value of high speed in preventing liquefaction in jacketed cylinders, that it is impossible to speak with any degree of accuracy with regard to it. The loss of pressure which takes place in the steam pipes and passages of high speed engines, and the importance of providing large passages, are, however, familiar to all engineers of experience, and there cannot be any doubt that the loss invariably shown in the combined diagrams of compound engines is due in a great measure to the resistance of the intermediate passages between the cylinders. It may safely be concluded, therefore, that any increased economy due to high speed is counterbalanced in a measure in the compound engine by increased loss between the cylinders.

So far as economy in actual working is concerned, it appears, therefore, that superheating or drying, wherever it can safely be resorted to, is quite as capable of application to the simple engine as to the compound; that the jacket can be used on the simple engine and on the low pressure cylinder of the compound engine, but that its use on the high pressure cylinder is objectionable, and that while increased economy may be expected from increased speed in both engines (and certainly so in the case of unjacketed cylinders), high speed is accompanied by an increase of the loss between the cylinders of the compound engine, the loss varying with the nature of the passages according to the form of engine.

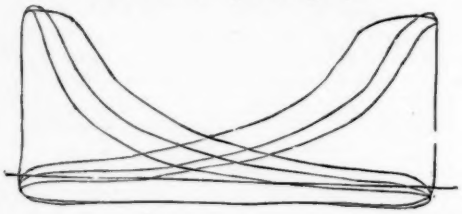
The most important lesson definitely taught by the American experiments is that which we have already indicated—namely, that expansion cannot be carried in jacketed cylinders with increased economy to so great an extent as has been supposed. In the simple engines tried, no provision against loss from the clearance spaces by cushioning in the exhaust was made, and the maximum efficiency of the steam was therefore reached at a lower grade of expansion than would have been the case had cushioning been provided for. The lowest consumption registered for the jacketed compound engine of the 'Bache' was obtained on the trial No. 7 (see Table 2), at the ratio of expansion 5.74, while in the simple jacketed engine the maximum efficiency appears to have been reached at the ratio 5.11 (trial No. 16, Table 2). As will be seen next page, the weight of steam used rapidly increased at the higher expansion in both types of engine, the loss being greatest in the simple engine and the unjacketed compound engine.

Referring to the diagrams from the 'Bache,' Fig. 3, it will be seen that the simple engine was worked at a disadvantage in the absence of cushioning, and this must necessarily have affected its performance to a considerable extent at the higher expansion. Taking the performances of the engines of both types as a whole, however, the soundness

BACHE.

	Simple Jacketed.		Compound.			
			Not Jacketed.		Jacketed.	
Ratio of expansion....	8.57	12.62	6.658	9.146	9.19	16.85
Weight of steam per effective horse-power.....lbs.	26.23	29.99	25.427	26.285	22.81	28.698

Fig. 3.—'BACHE.' SIMPLE ENGINE USING STEAM JACKET: Scale of indicator, 60 lbs. per inch.



of the conclusion arrived at by Mr. Emery, the designer of the engines of the 'Rush,' that a greater ratio of expansion than from 4 to 5.3 at pressures of from 60 lbs. to 80 lbs. is unnecessary, appears to be evident. In long-stroke, well-jacketed engines in which the losses from the clearances are reduced, either by cushioning or by reducing the clearances to a minimum, as in the Corliss system, expansion with saturated steam can undoubtedly be carried to a greater extent than this with a positive gain in economy, and in drawing conclusions from these trials the small size of the engines must also be borne in mind. Comparing, however, their performance with that of the much larger Chatham engines, and with the results given for the six hours' runs, it is evident that the American engines were very economical, the result given by the engines of the 'Rush,' with a ratio of expansion of 6.21 only, being remarkably good. There cannot be any doubt that the economy shown here was due in a great measure to the fact that expansion had not been carried too far.

In the commercial marine it is to the ships of the mail service that the simple engine is most applicable. It is here that competition in speed of ship is keenest, that the danger of disablement of the machinery is most to be dreaded, and it is also here that saving of space is most important, and that intelligent handling of the machinery can be depended upon. Of the most successful of the great lines engaged in the most important and most rapid steam-ship traffic in the world, that across the Atlantic, the ships of the White Star Line may fairly be taken as foremost in point of speed. The builders of these ships, Messrs. Harland & Wolff, of Belfast, have taken the lead in the construction of the long ships specially fitted for this traffic, and in the choice of a compound engine they appear, as in other matters connected with their vessels, to have exercised a sound judgment. The compound engines of the ships of the White Star Line, as most of our engineering readers will be aware, are of the vertical inverted cylinder type, having two cranks at right angles and four cylinders, the high pressure cylinders being placed above the low pressure ones with the pistons connected to one rod. Although probably not quite so economical as the type of compound engine with cylinders side by side, this form of the compound engine possesses for the service to which it is applied in the White Star vessels many prominent advantages. The continually increasing

power applied to the Transatlantic steamers has led to a corresponding increase in the dimensions of the cylinders, culminating apparently in the engines of the 'City of Chester,' fitted by Messrs. Caird with two cylinders of 72 and 120 in. diameter. The stroke of these engines is 5 ft. 6 in., the cylinders being placed side by side with the cranks at right angles. The difficulties to which the great size of the cylinders of this type of engine have led are many. The difficulty of obtaining sound castings, the impossibility of efficiently balancing the enormous weight of the low pressure piston and gear, and of distributing equally, under all conditions, the power transmitted to the two cranks, has given rise to endless trouble in the breaking of pistons, the failure of crank-shafts, and other mishaps.

In large steamers of recent build, in which the form of compound engine with high and low pressure cylinders side by side is adhered to, the capacity of the low pressure cylinder has been divided between two cylinders, there being thus three cylinders ranged fore and aft in the ship. With a compound engine the space taken up in this way is objectionably large as compared with that required for engines of the type in use in the White Star Line. In these engines also the effort transmitted to each crank is approximately equal under all circumstances as to variation of power, while as compared to the large engines of the 'City of Chester' type, for which the three-cylinder compound engine is being substituted, they undoubtedly possess great advantages in point of facility of handling and in manageable dimensions of cylinders. Taking success in the hardest service to which a steam engine can well be put—that of driving a steamer at full speed, in all weathers, across the Atlantic—as a test of efficiency, we do not think that a better selection could be made for comparison with a simple engine than one of the compound engines of the White Star Line.

Designation of Engine.	A.	B.	C. (Britannic)
Length of stroke.....feet.	7	5	5
No. of revolutions per minute.....feet.	60	60	58
Initial pressure taken at.....lbs.	60	60	60
No. of cylinders.....lbs.	2	3	4 { 2 H. P. / 2 L. P.
Diameter of each cylinder.....ins.	$62\frac{7}{8}$	$60\frac{3}{4}$	{ H. P. 48 / L. P. 83
Velocity of piston per minute.....feet.	840	600	580
Distance of cranks apart.....deg.	90	120	90
Maximum turning force on crank-pin (one engine)....tons.	71.8	67.2	75.7
Mean do. ... tons.	28.29	26.41	39.62
(*a*) Maximum twisting moment on crank-shaft (engines combined).....foot-tons.	311.8	248	269
(*b*) Mean do. foot-tons.	198	198	205
Minimum do. foot-tons.	105	170.5	172.5
$\frac{a}{b}$	1.57	1.25	1.31
Volume swept by piston per I. H. P. per minute.....c. ft.	7.22	7.22	{ H. P. 2.9 / L. P. 8.7
Total capacity of cylinders, showing the relative space which they actually occupy in the ship.....c. ft.	301	301	501

The engines are by various makers, but, taking the dimensions given for the engines of the 'Britannic,' recently engined by Messrs. Maudslay, we will endeavor to give an idea of the probable gain which might be expected to result from the adoption of simple engines in the Transatlantic steamers. In column C, in the table above, are given results calculated for the engines of the 'Britannic,' well known as being fitted with Mr. Harland's lifting screw. At about 58 revolutions per minute the engines develop their highest power of 5,000 horses, the volume swept by the pistons per H. P. per minute being then about

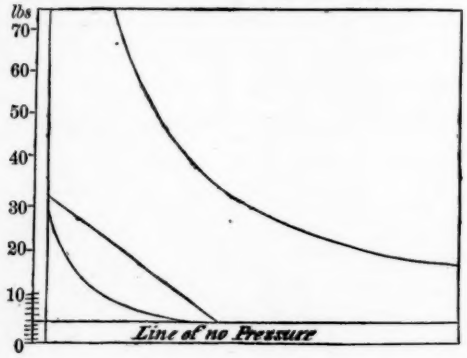
30 per cent. less than in the compound engines of the Royal Navy, particulars of which, when working at full power, have already been given. It will thus be understood that in selecting the engines of the 'Britannic,' we have taken a case in which one objectionable feature of the compound engine, that of a large cylinder capacity in proportion to the power developed, has been reduced to a minimum. We are not aware of any compound engine of large size in which the horse power has been produced with a less capacity of cylinder than in this ship.

In determining the capacity of cylinder for marine engines, the reduction of the pressure as the boilers become worn has to be kept in view, but for all practical purposes in the case we propose to consider this may be supposed to be provided for by basing the capacity of cylinder on the maximum horse power required, and on the maximum ratio of expansion which the recent experiments indicate as desirable.

Taking the ratio of expansion at 5, the clearances at one-fifteenth of the effective capacity, and making an allowance for cushioning, the volume swept by the piston per horse power per minute in the proposed simple engine would be 7.22 cubic feet, the indicator diagram being of the form shown in Fig. 4. Particu-

FIG. 4.

Saturated steam in jacketed cylinder $pr.\ \frac{9}{10} = \text{const.}$



lars of the engine are given in column A of the table. At 60 revolutions per minute the total effective cylinder capacity would then be 300 cubic feet in the simple engine for 5,000 H. P., against 500 cubic ft. in the compound, developing the same power at 58 revolutions. It will be seen that there is a gain here of 40 per cent. in capacity of cylinder as compared with the compound engine of minimum capacity.

In engine A this cylinder capacity has been divided between two cylinders of 7 feet stroke, an arrangement which would give the greatest advantages in point of simplicity. A gain in length of engine room (about 4 feet) would be obtained here, and presuming no back guides to be fitted, there would also be a considerable gain in height. The stroke would be eighteen inches longer than that of the engines of the 'City of Chester,' the diameter of cylinder, however, being little more than half that of the low pressure cylinder of this ship. Keeping this in view, and also the fact that the speed is obtained with only 2 revolutions per minute more than that of the engines of the 'Britannic,' which have two pistons, one of 83 and one of 48 inches, acting on one crank, it will be seen that, as compared with English practice, the speed of 840 feet per minute is not alarming, while as compared with the piston speed of the long stroke American engines the rates is moderate. It must also be borne in mind that we are dealing in all cases with the maximum figures.

Considerable importance is frequently

attached to the fact that the variation in the turning force due to the variation of the steam pressure during expansion is not so great in the compound as in the simple engine, although in view of the results given by the single crank engines of Messrs. Holt's steamers and the American single cylinder engines, it is not clear upon what grounds objections on this score can be seriously urged. The difference between the two engines we are comparing in this respect will be best understood from a graphic illustration.

In Figs. 5 and 6 is shown the turning effort due to the pressure of the steam

SIMPLE ENGINE A. 2 CYLINDERS. WITH CRANKS AT RIGHT ANGLES.

FIG. 5.

Turning forces combined for a complete revolution.

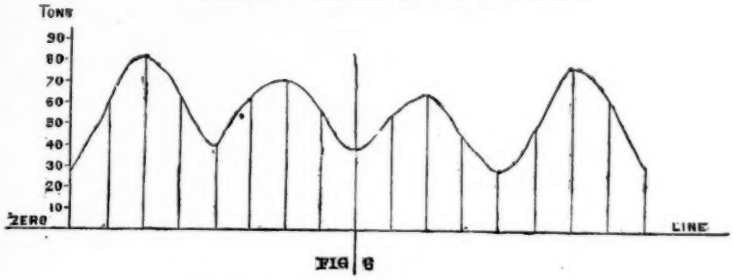
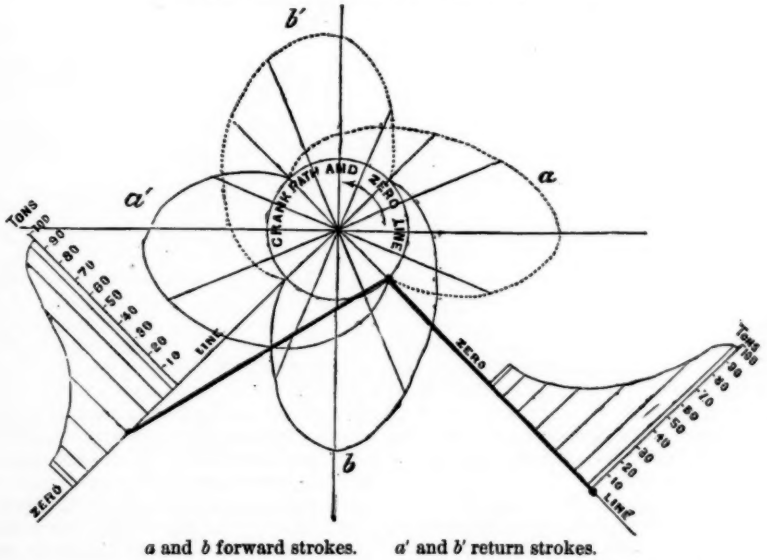


FIG 6

Turning forces on each crank-pin shown independently.



a and *b* forward strokes. *a'* and *b'* return strokes.

upon the crank pins of engine A for a complete revolution. In the lower diagram, Fig. 6, the turning effort on each crank is shown independently, and the pressure in tons upon the piston during a stroke is also shown. This diagram is arranged for the sake of clearances for an engine having the two cylinders placed at right angles, the effect being the same as if the cranks were placed at

right angles. For comparison diagrams arranged in the same way for engine C are shown in Figs. 7 and 8. The mean twisting moment on the crank shaft in the two engines is nearly the same, there being only the slight difference due

COMPOUND ENGINE C. 4 CYLINDERS. WITH 2 CRANKS AT RIGHT ANGLES.

FIG. 7.

Turning forces combined for a complete revolution.

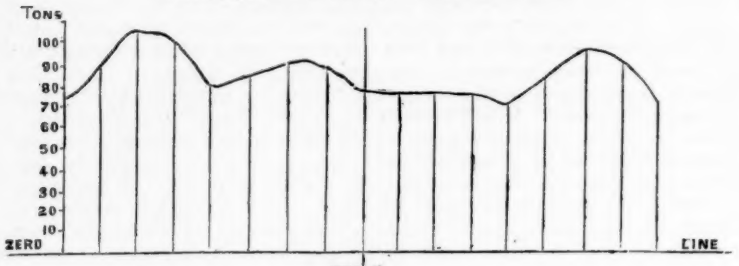
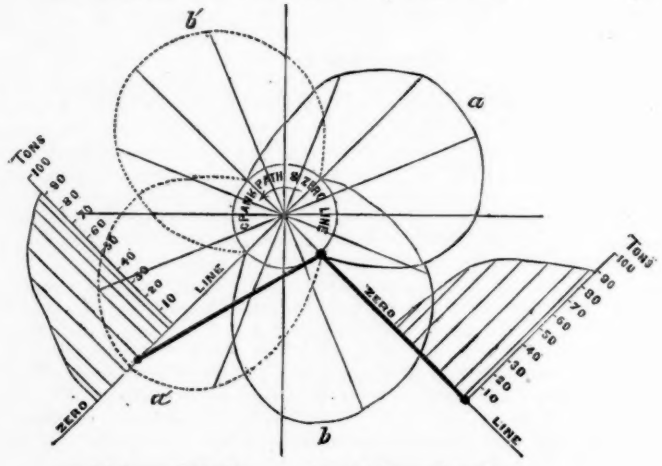


FIG. 8

Turning forces on each Crank-pin shown independently.



a and *b* forward strokes. *a'* and *b'* forward strokes.

to the difference of 2 per minute in the revolutions. On referring to the diagrams and table, however, it will be seen that the mean turning effort on the crank pin is only 28 tons in engine A against 40 tons in engine C. The *bete noire* of the engineer at sea, a hot bearing, is due, as a rule, when not occasioned by the use of improper materials or bad construction, simply to excess of pressure at the surfaces in contact. There is ample evidence in practice that bearings can be run at almost any speed without danger of heating if the pressure upon them be not too great. The friction of sliding surfaces, as a matter of fact, appears to decrease as the velocity increases.* "Friction diagrams" taken from marine engines at different speeds show an increase in the power required to

* This was shown to be the case in a number of experiments described in a paper by M. H. Bochet, an abstract of which appeared in the *Comptes Rendus* of the French Academy of Sciences for 1858. See Professor Rankine's *Machinery and Millwork*, p. 349.

drive the engine at the higher speeds, but the increased resistance shown is, no doubt, chiefly due to the increased power required to drive the pumps at the higher velocity.

An increase of the length of stroke not only reduces the turning effort on the crank pin, but it also reduces the direct thrust on the shaft bearings, and for engines of the same type the diminution of the loss from friction and tendency to heat the bearings may be taken as directly proportional to the increase in the length of stroke. It will be seen, however, from the diagrams, that, although the mean turning force is much less in engine A than in engine C, there is a greater irregularity in the force transmitted to the crank, and it might, therefore, be supposed that some loss from this cause might be found in practice. There is direct evidence, however, in the trials of the gunboats 'Swinger' and 'Goshawk,' which we have frequently quoted, that there is no loss of efficiency from this source. Diagrams from the 'Swinger,' fitted with simple engines, have been published in the Prize Essay of the Junior Naval Professional Association, and from them it is evident that the inequality in the turning force must have been considerably greater in this case than in engine A. Both on the measured mile trials, when tried at the same draught of water, and when the boats were run side by side, the results were slightly in favor of the engines of the 'Swinger." The six hours' run side by side may be taken as practically conclusive on this point, the displacement coefficients being 152 for the 'Swinger,' against 148 for the 'Goshawk.'

The comparison we have here made between a simple engine and a compound engine of type C is the more interesting as we have direct evidence in the American trials as to the relative economy of the two forms of engine. The engine of the 'Bache,' as already stated, has the high pressure cylinder on the top of the low as in type C, and the trials, particulars of which are given in Table No. 2, show that there was a positive gain in economy by using the low pressure cylinder as a simple engine when the jacket was used as compared with the compound engine not using the jacket. In comparing the two types of engine for absolute economy, it is evident that when the high pressure cylinder is dispensed with there is a reduction of the friction of the moving parts to the extent due to this cylinder, and that there is therefore a corresponding increase in the power available for useful work. The friction pressure for each cylinder was determined in the American trials, and the two forms of engine can therefore be compared in a rational manner by taking the weight of steam used per effective, or, as termed by the American engineers, "net" horse power, as a measure of their absolute economy. On referring to Table 2 it will be seen that the short trial No. 1 of the compound engine with the jacket shows a considerable gain by the use of the compound engine, but the accuracy of the results of this trial is not borne out by the figures given for the seven hours' trial, No. 8, at the same ratio of expansion, which shows a gain of only 3 per cent. by compound expansion. Some gain would certainly have resulted from cushioning in the simple engine, so that practically the same economy might have been expected from the two engines with the jacket in use in both cases, while there appears to be no room for doubt as to the actual superiority of the simple jacketed engine as compared to the unjacketed compound engine in the case of the 'Bache.'

From the various particulars we have given it will be seen that the performance of engines is affected so seriously by the initial condition of the steam used, by the speed of piston and by the proportion and size of the cylinders, that it is very difficult to arrive at a correct conclusion as to the real cause of different results being given by engines working under the same conditions as to boiler pressure and rate of expansion. A comparison of different engines must, therefore, always be a dubious one. In the case of the 'Bache,' however, we have the same cylinder supplied by steam from the same boiler and with the engine running at the same speed, the result being that given above. It is evident that the best that could be said in favor of the addition of the high pressure cylinder to this engine would be that it enabled the jacket to be in a measure dispensed with, and it need hardly be point-

ed out that a complete cylinder, with all its fittings, is rather an expensive substitute for an independent liner fitted in a simple cylinder.

Taking the particulars we have given as a whole, the result of the comparison we have made can hardly be considered otherwise than as favorable to engine A, the only dubious points as compared with English practice being the increased length of stroke and the higher speed of piston. With the same capacity of cylinder as in engine A, however, a three cylinder simple engine could be made which, with the same length of stroke and speed of piston as in engine C, would be decidedly superior to this engine in regularity and balance of turning forces. Particulars of an engine of this kind are given in column B of the table, and crank effort diagrams are given under (Figs. 9 and 10).

SIMPLE ENGINE B. 3 CYLINDERS. WITH CRANKS AT 120°.

FIG. 9.

Turning forces combined for a complete revolution.

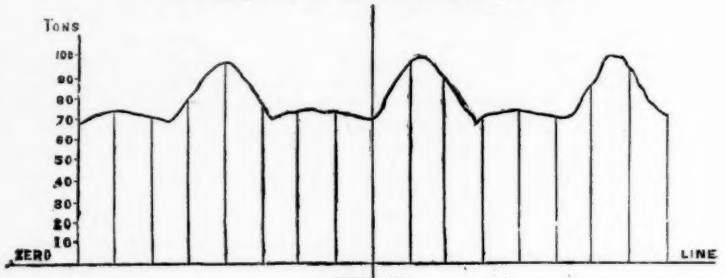
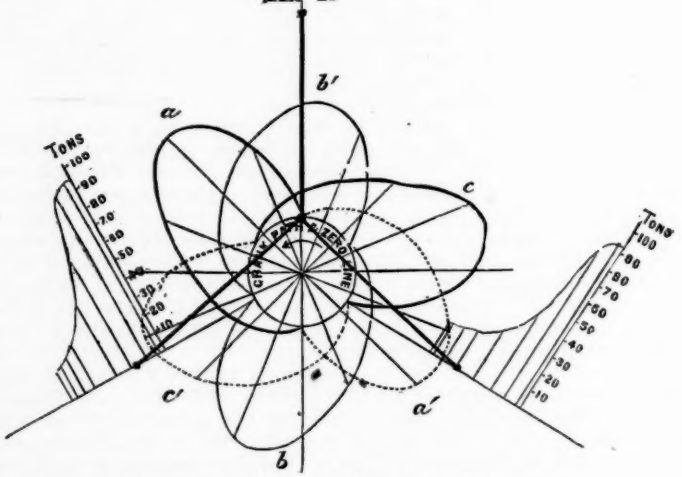


FIG. 10



a b c forward strokes. *a′ b′ c′* return strokes.

This is the form of high pressure simple expansive engine, the use of which is advocated for ships of war in the Prize Essay we have quoted from, special provision being proposed to be made for readily disconnecting the cylinders at low speeds, or when disabled. In the more important ships of war the difficulty to be met with is, that on extraordinary occasions, as when chasing or being chased, a power of about six or seven times that ordinarily required

must be available, and it is essential that sufficient capacity of cylinder be given to insure economy in the engine itself at the highest power. It is then that waste from forced firing, and from generally decreased efficiency of the boiler, takes place, the enormous quantity of coal expended, and the comparatively small quantity which can be stowed in the ship, necessitating the utmost economy under these conditions. In working at the lowest powers with the large cylinder capacity thus necessarily provided, enormous loss from condensation takes place, and the only effective way out of the difficulty is to disconnect a part of the cylinder capacity entirely. The three cylinder form of engine, therefore, presents for this service many advantages, the American experiments rendering it evident that, with cylinders fitted to disconnect, such an engine would be more economical than a compound engine using the whole of the cylinder capacity (and with inter-dependent cylinders this is necessarily the case) at low speeds.

In the service to which our remarks have been directed, however, the range of power required under ordinary working conditions is slight, the ship being usually driven at nearly the full power the engine is capable of developing, and except in the case of larger powers than that of the present steamers, there appears to be no necessity for introducing a third cylinder. Keeping in view the results given by the American single cylinder engines and the engines of Messrs. Holt's steamers, it could hardly be expected that any gain of commercial value would be obtained by substituting, in the case we have considered, a three cylinder engine for engine A, with the the object of gaining greater efficiency of the mechanism.

We trust we have succeeded in placing prominently before our readers the fact that all the available evidence shows that practically equal results in point of economy of fuel may be obtained with either type of engine, when the same pressure of steam is used under the conditions we have chosen for illustration. Let this be understood, and the gain in space, weight, simplicity, facility of handling, the less liability to total break downs, and less first cost of the simple engine when intelligently designed be fairly realized, and shipowners on this side of the Atlantic will, no doubt, give it further trial. American experience shows that so far as wear of pistons and cylinders is concerned, jacketed engines of this type can be kept in perfect order, while the experience gained with the high pressure valve gear of the compound engine has enabled engineers to meet with confidence the difficulties arising from the increased pressure of the steam so far as it affects the wear of the valves. Difficulties of this kind, to which, together with unnecessary large cylinders, the unsatisfactory working of simple engines on this side of the Atlantic may be traced, are now being met on the largest scale by the eminent firm of Messrs. John Penn & Son, who have in hand for ships of war two sets of engines, amounting to an aggregate power of 10,000 horses. These are intended to work at their full power as simple expansive engines, and we have no doubt that other firms of equal enterprise are prepared to construct simple engines, specially fitted for the Transatlantic traffic, which, there is every probability, would be found to work with greater satisfaction to the engineers and shipowners than the cumbrous machinery now in general use.

Captain Eads has had compiled the following interesting and scientific data cencerning the Mississippi River, the work at whose mouth he has already begun: 1. Quantity of water discharged by the river annually, 14,883,360,636,880 cubic ft. 2. Quantity of sediment discharged annually, 28,188,083,892 cubic ft. 3. Area of the delta of the river, 13,000 square miles. 4. Depth of the delta, 1,056 ft. 5. The delta, therefore, contains 400,378,429,440,000 cubic feet, or 2,720 cubic miles. 6. It would require for the formation of one cubic mile of delta, five years and eighty-one days. 7. For the formation of one square mile, of the depth of 1,056 feet, one year and sixteen and 1-5 days. 8. For the formation of the delta, 14,268 4-5 years. 9. The Valley of the Mississippi from Cape Girardeau to the delta, is estimated to contain 16,000 square miles of 150 feet depth. It, therefore, contains 66,980,160,000,000 cubic feet or 454½ cubic miles.

ENGINEERING ON THE DANUBE.

From "The Building News."

For many years it has been debated among engineers whether the natural obstructions to the navigation of the Danube might not be, by the aid of science, removed. The obstacles were two—the one, however, closely associated with the other—a set of dangerous rocks, and a series of equally dangerious rapids. A project had long been matured, by a company of American speculators, to clear this important channel; but political considerations intervened, and a great European water-way was left in something like the condition of a half-choked canal. The reason was that, as usual, rival schemes were contemplated, as in the case of the Tiber, to which we lately referred. There was, for instance, the idea of a canal, to run parallel with the stream; there was the proposal to blast away a shelf of rocks forming the Orsova rapids; and there was also the suggestion of blowing up the Iron Gates, or granite bar, crossing the entire breadth of the river, and checking even the light Austrian Steamboats on their course. Here the water, as a rule, though its flow is wide, has a depth of no more than twenty inches, and the inconvenience to traffic of all kinds is enormous. The work, however, although decided upon so long ago as 1871, remains to be carried out in its entirety, when the celebrated Iron Gates will be no more, and Trajan's towing-path a mere memorial of antiquity. Now, the Danube, through its position in Europe, the extent of its available course, the importance and wealth of the territories traversed by it, should rank as the first river of Europe, a great facility for inland communication, and a grand link between the land and sea.

With the public influences which have hitherto established a sort of blockade upon its waters this present writing has nothing to do, the question for us being whether a generation that has canalized the Isthmus of Suez, and tunnelled the Alps, should allow the splendid border stream, as it may almost be termed, of the Continent, to be trammeled by a complication of geological embarrassments. It was thus, in an almost similar degree, at one period, with the Rhine. The Rhine had, naturally, no navigable outlets; it had no mouths; its only practicable way to the ocean was stopped by a bar, and it took a quintuple treaty to get rid of this obstruction. A convention of the same character set the Dunube free to the flags of all nations; but it did not blow up the rocks, or abolish the rapids. The Danube is, perhaps, regarded from a practical point of view, the most remarkable river in Europe. After cutting through the chalk mountains which stretch from north to south between the Balkan and Carpathian ranges, in a narrow channel where the waters boil, as if with impatience to escape, it widens like the Nile, intersects a valley nearly a hundred miles in breadth, passes under precipices on one side, and along marsh lands on the other, branches in every direction, forms clusters of islets, and then rebels against the Iron Gates. Two commissions of French and American engineers have reported that these are the main impediments to the utilizing of the river, which at its *embouchure*, gives soundings of fifty fathoms, on a bottom of shell and sand—a fact clearly proving that the Gates lock up, or largely obstruct, the possible trade of the interior. In spite of all this, not many years ago the accumulations at the entrances of the Danube absolutely closed them against vessels of even moderate tonnage; the mud and silt rose yard by yard in height; a few cyclopean rakes were idly employed in the attempt to remove them, and the Russian Government ordered a dredging machine, which, after having been worked for a very short time, was declared to be out of order, and has been laid up in ordinary ever since. But the scour of the stream, supposing the barriers farther up the valley removed, would have effected more than all the dredging engines ever manufactured. And what is the interest of the world in this grand artery of intercommunication,

concerning which the engineers are so busy just now? The Danube, which it is proposed, to unite by a canal with the Adriatic—although the proposed cost of the schemes has frightened even its projectors—begins its navigation at Ulm, an emporium of merchandise from France, Germany, and the banks of the Rhine. In its course it passes through the territories of four States, and receives the tribute of a hundred and twenty rivers. But the Iron Gates—the Porta Ferrea of the Romans—close the upper valley against all craft except the class of barges; and even these, when heavily laden, often find themselves stuck, most unwillingly, in rocky labyrinths, or on heaps of sand, even supposing them to have passed the thirty miles of broken rapid, which, it is now believed, may be blasted into a smoother bed. That such labor was, at one time, regarded as being among the Quixotisms of speculative science is shown by the gigantic expenditure and toil bestowed upon tunneling a carriage-way through the body of perpendicular rocks here overhanging the river—a work effected by gunpowder throughout, and quite equal in grandeur to the artificial road of the Simplon. But all modern enterprise, as yet, has failed to emulate the mighty monument of the Romans in that historic valley. Those Builders did not excavate; their tools and other appliances did not serve them adequately. They, therefore, constructed a covered gallery of wood along the face of the precipices, supported by strong buttresses, projecting over the stream, at the height of about six feet above its greatest altitude, and extending for a distance of nearly fifty miles. The holes for the reception of the horizontal buttresses on which the platform rested are as perfect now—as we have seen them—as they may be imagined to have been sixteen centuries ago; and, although the continuous line is occasionally interrupted by the dense masses of brushwood which have sprung up with the lapse of time, their course may be distinctly traced along the base of the mountains. In many places, indeed, a double set of holes may be observed, as if the lower ones had been constructed to receive brackets to aid in supporting the buttresses above. All antiquity notwithstanding, however, the principle importance in connection with every subject of the kind belongs to the present day; but it is especially interesting to note how, while awaiting the final triumph of engineering enterprise over the difficulties of the Danube, they have been lessened and mitigated for the sake of transit and commerce. The Austrian Danubian Steam Navigation Company, founded about forty years ago, and building and buying in the valley itself, though getting much of its machinery from Switzerland, works over three thousand miles of water, and keep five powerful dredging-machines, strangely enough, in constant employment. The operations forthwith to be undertaken will relieve them from this neccesity. They comprise a blasting and an embankment, and will be watched with curiosity from every quarter of Europe. It is believed that the cost of the works will be considerable less than that at which it was estimated by the American projectors, but they, it should be remembered, included in their design a lateral canal, with three approaches to the sea. The Commission of Austrian and Turkish engineers who, during the last two years, have been studying the problem on the spot, has not, indeed, reported in the most favorable terms; but their opinion, nevertheless, sanctions the idea, and suggests a plan for defraying the expense of developing it. That the Iron Gates are still practically shut is a reproach to the civilization of Europe; that they should remain so indefinitely seems impossible. England, at a far greater cost than is now threatened, cleared the important Paumban Pass, now the great water highway between Ceylon and the mainland of India, and sounded and measured every depth and shallow of the Red Sea. It would appear, then, to be a paradox now that a splendid river, such as the Danube is, should be closed against the higher necessities of trade and passage by a few bars of rock, and a few miles of rapids, which engineers declare may be blown out of the way without difficulty or danger. The Danube is to Europe what the Mississippi is to America—"the father of waters," and only requires a clear channel to become next in importance to a sea. Mechanical objections there are none to its perfect physical liberation.

ROTARY PUDDLING.

From "Engineering."

If we may judge from the interest manifested in the remarks made by Mr. Menelaus in his inaugural address to the members of the Iron and Steel Institute, and from the reports which reach us from the various ironmaking districts, the problem of mechanical puddling is now being regarded as of ever-increasing importance. Our own views on this subject are well known to our readers. We regard the present system of hand-puddling as a blot upon the progress which has been made in our iron manufacture, and as entirely inconsistent with the growth of our metallurgical processes. As we have pointed out on more than one occasion, the whole tendency of the modern development of our iron manufacture is towards the treatment of the material in large quantities, and with the aid of the least possible amount of hand labor; but the ordinary puddling process is totally opposed to this kind of development, the material being treated in small charges, and by the exertion of manual labor of the most severe kind. Considering these facts we think that everything tends to show that the puddling process of the future will be carried out in rotary furnaces capable of dealing with large charges, and worked in connection with plant capable of dealing easily with the enormous puddle balls thus produced, these balls being subsequently cut into pieces of convenient size and dealt with by existing machinery; and we believe that the time has arrived when our ironmasters should, as a body, consider this subject more earnestly than they hitherto have done. In making this last remark we have no desire to underrate the progress which has been already made; but this progress has been due rather to the energy of a few particular firms and individuals than any action taken by the iron trade as a whole, and it has thus been smaller than it need have been.

The only united action which has taken place has been that organized under the auspices of the Iron and Steel Institute—a body which, although the youngest of our important scientific societies, has set an excellent example to its seniors by its energy in promoting the industries it represents. As we pointed out on a recent occasion, the commission sent to the United States by the Iron and Steel Institute to examine into the working of the Danks furnace, has been attended with valuable results. It is true that, as regards the Danks furnace itself, the early anticipations set forth by the report of the commission have not been completely fulfilled; but this we regard as a small matter compared with the fact that English ironmasters have been familiarized with the results which can be obtained by rotary puddling, and that competent men, such as Siemens, Spencer, Crampton, and others, have been led to experiment further with that system of puddling, and to contribute towards making it a thorough success.

The process of mechanical puddling is essentially one requiring to be developed by experimental inquiry. To be commercially successful, machinery for puddling mechanically must not only be capable of turning out a product at least equal to that obtained by ordinary hand work, but it must also be enduring and be capable of being worked without "nursing" and without giving trouble from frequent breakdowns. It is this quality of endurance under the rough usage experienced in iron works which has proved so difficult to obtain in puddling machinery, and it is a quality the possession or non-possession of which in many instances, can only be determined by actual practice. We say in many instances—not in all—for there have been undoubtedly cases of the introduction into iron works of puddling machinery which would have been at once condemned at sight, had it come under the inspection, of a competent mechanic. Setting aside these exceptional cases, however, we may assume it to be an undoubted fact that the capabilities of puddling machinery can only be fairly tested by actual practical experience, and this being so the various failures of such machinery which have occurred, can only

be regarded as so many stepping-stones deposited on the road to success.

Thanks to these failures, indeed, and to the labors of those who have endeavoured to overcome them, we may say that at the present time mechanical puddling has been made a practical process, and has been brought to such a stage that its future development depends less upon individual exertion than upon its introduction into various iron-making districts and the consequent improvement of details of manipulation certain to result from more extended experience.

When the Danks furnace was first introduced into this country, it was in many quarters assumed—somewhat too hastily—that it was practically perfect, and the earlier experiences of Mr. Menelaus, Tooth, and others in the same field were temporarily forgotten. Practical trials, however, on a commercial scale developed more or less serious difficulties in the working and maintenance of the furnace, and from that time to the present constant efforts have been made to effect improvements. The present state of the matter as far as the Danks furnace is concerned is fairly set forth in the letter from Mr. Jones, of the Erimus Works, incorporated in the inaugural address of Mr. Menelaus, already referred to, and published by us the week before last. According to Mr. Jones the difficulty of the lining has been entirely overcome and "fettling can be procured suitable to any district," while he also speaks in hopeful terms of the means adopted to reduce the tendency to mechanical failures. As we pointed out a fortnight ago in our comments on Mr. Menelaus's address, the leading improvement introduced in the modified Danks furnaces at the Erimus Works—namely, the water-jacket arrangement—is one of the chief features in the Crampton furnace. We have no intention here of entering into any discussion relating to priority of design; but the fact of the Danks furnace being thus made to approximate in construction to the Crampton furnace as regards the mode of cooling by water irresistible suggests certain comparisons between the two systems of working, which in the present state of the puddling question are worthy of consideration.

As regards speed of working, there is probably nothing to choose between the two systems so long as both furnaces are in equally good condition; but in regular work the amount of the output from any given furnace is of course largely dependent upon the ease of maintenance of that furnace. As to what would be the relative endurance of two furnaces, each constructed on Mr. Crampton's plan with water-jacket arrangements, but one worked on the Danks system and the other with dust fuel, there are no data for actually determining; but there are certainly no reasons for believing that the results would be in favor of the former. With reference to this point we may remark that in the Crampton furnace the 5-in. cock revolving with the casing and through which the water supply enters the latter, is not liable to derangement, and has stood the test of long practical working, while this can scarcely be expected to be the case with the Danks furnace, as to effectively supply water to the latter involves the use of what may be regarded as a revolving cock 7 ft. in diameter, the wearing surfaces of which have thus a comparatively high speed. As regards quality of product, the difference, if any, may fairly be expected to be in favor of the Crampton furnace, on account of the high and uniform temperature which can be maintained and the regularity of the working—both matters which practice has shown to be of a vast importance. Taking, therefore, even the view of the question most favourable for the Danks system, we see no reasons why that system of working should, as regards quality or quantity of products, show any advantage over that of Mr. Crampton.

If now we consider the matter further, and examine the other qualifications which go to make up a successful rotary puddling furnace, we find that Mr. Cramptons's system possesses most important advantages. Thus, in the first place, the use of the dust fuel as carried out by Mr. Crampton gives a power of controlling the action of the furnace which is utterly unattainable so long as ordinary fires are used. We have frequently spoken upon this point, and the continued experience at Woolwich only serves to confirm all we have said. By shifting the handles regulating the sup-

plies of air and fuel, the temperature can be altered or flame made oxydizing or non-oxydizing at will, without a partical of coal getting into the iron, while by simply leaving the handles alone any given condition can be maintained for hours, if desired, absolutely without trouble. The ease and completeness with which the combustion of dust fuel can be controlled is, in fact, so striking that we are inclined to think that it can only be thoroughly appreciated by those who have examined it in operation, and who are, at the same time, conversant with the difficulties of managing ordinary fires. One result of the perfection of the combustion obtained with the dust fuel is the rapidity with which the furnace can be heated, the Woolwich furnace, when cold, having been repeatedly raised to a working heat in three-quarters of an hour with an expenditure of three and a half cwt. to four cwt. of fuel.

Another advantage of the Crampton system of working is that it does away with the construction and maintenance of all brick-built furnaces, and leaves the revolving furnace itself quite free at one end, the products of combustion returning through the same opening through which the jets of dust fuel are injected, and the furnace forming within itself a gas producing, gas consuming, and puddling chamber. We may remark, by-the-by, that during his earlier trials Mr. Crampton employed two chambers, but the alteration of the furnace so as to have one chamber only was found to save at least one-third of the fuel. Moreover, the Crampton furnace, instead of having two revolving joints to keep tight (to prevent the liquid iron from escaping), as in the case with Danks', has one only, while every facility is given for the expansion and contraction of the revolving furnace itself. All firebars, too, are done away with. These, we think, are mechanical advantages having no unimportant influence on the cost of maintenance, while as collateral advantages we have the effective utilization of slack coal and its combustion without the production of smoke. The fact of the fuel being conveyed to the Crampton furnaces by mechanical means, and all wheeling of coal to the furnaces being thus avoided, is also a feature of the system which should be borne in mind.

The Crampton furnace at Woolwich, after being in operation two years, was when we last saw it a few weeks since, in as perfect condition as when it left the boiler-maker's hands, it not even showing signs of distortion. During its working the liquid iron never issues from the revolving joints, while the friction is so small that the engines driving it require less than one-fourth the capacity of those found necessary on the Danks system. During the working of the furnace at Woolwich, there have been puddled, alone and mixed, large charges of Swedish charcoal iron, hematite, Northamptonshire, Derbyshire, South Yorkshire, and Cleveland irons, and judging from the exhaustive tests applied, the Cleveland pig has produced tin-plates, sheets, wire, rails, bars, and plates equal in quality to the products obtained from the best brands. Moreover, the steel made in pots and in the Siemens-Martin furnace from Cleveland puddled bars has proved equal to the best pot steel produced from Swedish charcoal iron. Most of these results were obtained during the time that the furnace was under the charge of independent manufactures who, after treating the puddled blooms in their own works, forwarded samples of their products to Mr. Crampton, who has thus been enabled to arrange at his offices at 4 Victoria Street, Westminster, a most remarkable and instructive collection of materials produced by mechanical puddling—a collection which is well worthy of examination by those interested in the subject.

Altogether when we consider the numerious advantages attendant upon the employment of fuel in the form of dust, and the general excellence of the mechanical arrangements which Mr. Crampton has designed and practically carried into effect for the utilization of such fuel, we cannot but regard the Crampton furnace as the most advanced solution of the problem of mechanical puddling, and we look forward with very considerable interest to the results which may be expected as soon as the Crampton furnaces now nearly completed in the Middlesbrough district are fairly at work ; our interest being, we are sure,

shared by all concerned in our iron manufacture. It is anticipated that these results will be even superior to those already obtained at Woolwich, and from the completeness of the arrangements we have every hope that this anticipation may be realized.

REPORTS OF ENGINEERING SOCIETIES.

MASTER MECHANICS' ASSOCIATION.—The following are the subjects for investigation and discussion the coming year, as reported by the Committee on Subjects, consisting of Reuben Wells, James M. Boon and John H. Flynn :

1. Locomotive Tests.
2. Best Material, Form and Proportion of Locomotive Boilers and Fire Boxes.
3. Locomotive Construction.
4. Locomotive Tire, Truck and Tender Wheels.
5. Best and Most Economical Metal for Locomotive and Tender Journal Bearings.
6. Is it Economical to use Injectors on Locomotives, and to what Extent ?
7. Boiler Explosions.

There were reports on the first four of these last year, but the subjects and committees were continued.

The following is the report of the Committee on Narrow and Broad Gauge Rolling Stock : *To the American Railway Master Mechanics' Association*:

GENTLEMEN—Replies were received from twelve roads, and the information obtained is embodied in accompanying table. Very full reports were made by Mr. Peddle, of the St. Louis, Vandalia, Terre Haute & Indianapolis R., and Mr. Wells, of the Jeffersonville, Madison & Indianapolis R.

To the question, "From your experience, which is the best gauge, narrow or ordinary (4 ft. 8½ in.)?" Mr. Peddle replies as follows:

"From my experience I would prefer 5-feet gauge to either of the other gauges, for two reasons: The first is, that a wider wheel-base would enable the modern raised-deck coaches and sleeping cars, in which the centre of gravity is much higher than in the old-style coaches, to be run with greater steadiness and freedom from oscillation at high speeds. Another reason is, that it would give locomotive builders more room between the frames and enable them to lower the barrel of the boiler, and also widen the fire-box and do away with the off-set in the sides, in the vicinity of the tubes, a very objectionable feature, and make them straight or narrower at the top."

The information in relation to narrow gauges (viz., less than 4 ft. 8½ in.) is too meagre to make a fair comparison between them and the ordinary gauge.

From the table it will be seen that five prefer 4 ft. 8½ in. or 5 ft. to the narrow gauge or gauges. Two prefer gauges of 3 ft.

WM. S. HUDSON,
H. G. BROOKS,
H. N. SPRAGUE, } Committee.

—*Chicago Railway Review.*

IRON AND STEEL NOTES.

CARBURATION OF IRON.—M. Boussingault has communicated the results of his experiments on the combinations of carbon, to the academy of sciences of Paris. M. Boussingault has found by most careful experiments that carbon exists in carburated iron in various proportions. Steel contains from 7 to 10 1000th parts when hard, and soft 10 to 15. Pig-iron contains 2 to 4 100ths, and sometimes 5 100ths. The quantity is difficult to settle, as it can only be ascertained in analysis by the difference with manganese, silicium, phosphorus, sulphur, and chromium. The average of the results is 4 4c. When gray the iron has given up its carbon in the form of graphite; but M. Boussingault found no sensible difference in the quantity of carbon in gray and white pig. In all cases, if the real combination of iron with carbon be admitted, it takes place thus—5 equivalents of iron for one of carbon. Whatever be the temperature it is impossible, says M. Boussingault, to make more than 5 per cent. of carbon enter the iron ; this is the limit.—*Iron.*

UTILIZING FURNACE SLAG.—Mr. W. Harold Smith, of this city, has been experimenting for some time with furnace slag, endeavoring to make from it a cheap and serviceable substitute for bricks and stone in paving and building. He has taken slag, from Robbins & Sons' Philadelphia Furnace, granulated as it came from the stack, then mixed it with two-thirds its weight of cement, subjected it to heavy pressure, and has succeeded in making firm, smooth, solid blocks, which have endured the following tests: They have been very highly compressed without crushing, were laid for pavement last fall and endured the winter's frost without damage, have been heated to a white heat and then thrown into water without disintegration, a 35-foot column of water was forced against one of the blocks without penetrating it, and they were found to endure heat which would melt an ordinary red brick.

Mr. Smith proposes to unite with any furnace owner in the manufacture of stones for flagging sidewalks, from 15 to 24 inches square and 3 inches thick, afterwards, as the demand improves, entering into the manufacture of other forms; or he will sell a furnace right at a reasonable figure. Mr. Smith claims that his stone, which he has named "Phœnix stone," can be made so cheaply and sold so readily that a furnace owner can make as much out of his slag as he can out of his iron. His address is 227 North Thirteenth Street, and his office is at 224 South Third Street, Philadelphia. He solicits correspondence, and invites attention to samples of "Phœnix stone" on exhibition at the office. We have seen these samples and believe they will make a good substitute for stone or brick. —*Bulletin.*

BELGIAN COMPETITION IN THE IRON TRADE. —Now there is so much talk of Belgian competition with our iron manufacturers, the following passages from the report of Sir H.

Barron, on the commerce, &c., of Belgium, just published among the reports of her Majesty's Secretaries of Legation, may be read with some interest. The competion, it would appear, must have arisen from the general depression in the iron trade first reaching Belgium, so that Belgian manufacturers were forced to great sacrifices to find a market of any kind. At any rate, Belgian trade has not been prosperous :—"On the whole," Sir H. Barron says, "the activity of all branches of trade in 1872 was rare and unparalleled. Above all, the trade connected with the manufacture and working of iron enjoyed an exceptional prosperity. All the smelting furnaces, iron works, rolling mills, machine works, foundries, and nail makers worked without intermission during the whole year. Many new factories were erected, many of the old ones were enlarged. At the same time the price of iron and its products rose. without a check from the beginning to the end of the year, to figures previously unknown. Pig-iron doubled in value during the twelve months. These prices left the producers good profits during the first six months. But the prices of labor and of coal rose to such exorbitant rates as to absorb finally the whole profits of the iron trade. Thus, the year which began so rich in promise ended in disappointment. The masters now find that they cannot tempt buyers at the present prices of iron, and cannot reduce those prices on account of the excessive cost of production. Many works have been closed and furnaces blown out in 1873, so that the trade is falling into a state of general stagnation. The present year will leave no profits to the iron-masters in general, save to such as possess colleries of their own, as, for instance, the monster establishments of Seraing, Couillet, Solessin, &c." Our trade, therefore, has not been suffering from the competition of prosperous Belgian ironmasters who were making a profit when our makers had none, but from manufacturers who were unable to get profitable orders.—*Iron.*

THE U. S. COMMISSION ON TESTING METALS.—The following circular has been recently issued:

The U. S. Commission on the Tests of Iron, Steel, and other Metals, proposes making a series of determinations of the effects of carbon, phosphorus, silicon, manganese, and other elements, upon the strength, toughness, elasticity, and other qualities of Iron and Steel. The specimens will be analyzed by the chemists attached to the Commission and subjected to tension, torsion, compression, and other mechanical tests. All experiments will be repeated often enough to reduce errors to their minima.

You would greatly aid the Commission, as well as the Iron Trade, by furnishing Iron and Steel bars, as follows:

Bars to be 7 ft. long and 1¼ in. round.

Bars to be rolled, in case you have suitable rolls; if not, hammered billets, 3 in. square by 18 in. long, to be furnished in place of bars.

Bars to be stamped on one end with the initials of the maker, and the number of the heat or charge at which they were made; or, in case there is no such record, to be stamped with the initials of the maker and numbered on one end.

A full description of the kind and make of raw materials, and of processes employed in the manufacture of the bars, and also of the size of the ingot or pile, the number of reheats, and the extent to which hammering or rolling were employed in the reduction, to be kept in a reference book—each description having a number corresponding with that of the bar—would be of great value. Such a record is, therefore, particularly requested.

Your own analyses, including color carbon tests—in case you have made them—to be given in the above description.

Your mechanical tests of the material furnished, with statement of shape and dimensions of specimens tested, to be also recorded and furnished.

Please store the bars until the Commission informs you where to send them.

KIND OF IRON AND STEEL WANTED.

Any or all the following:

1	bar of	Steel,	containing	.....	0.10 % carbon.
1	"	"	"	.....	0.20 "
1	"	"	"	.....	0.30 "
1	"	"	"	.....	0.40 "
1	"	"	"	.....	0.50 "
1	"	"	"	.....	0.60 "
1	"	"	"	.....	0.70 "
1	"	"	"	.....	0.80 "
1	"	"	"	.....	0.90 "
1	"	"	"	.....	1.00 "

After selecting these bars by means of your carbon tests, please repeat the tests, so that there may be no error.

It is very important that the other elements should be uniform; therefore, these bars should be selected from charges made as far as possible from the same raw materials, and under similar conditions.

Also, please furnish—1 bar of each of such Irons or Steels as may show any particularly good or particularly bad qualities, or such as may exhibit any very marked or unusual characteristics.

1 bar of your best wrought Iron, with its trade mark stamped on.

1 bar of very hard, but not cold short wrought Iron.

1 bar of extremely soft wrought Iron.

1 bar of average "puddled Steel."

Any bars which you think may be usefully subjected to these tests—specially describing the materials and processes employed in making them, and their characteristics.

When the bars are tested, it is proposed to test a series in which the manganese varies by tenths of a per cent., other elements remaining the same, and another series for phosphorus, and so on.

Tool Steels will be tested in another series of experiments.

These determinations must, of course, require thousands of specimens, and be continued through a series of years. The final result must inevitably lead to a scientific syn-

thesis in the Iron and Steel manufacture, by which all required mechanical qualities can be accurately produced at pleasure.

A. L. HOLLEY,
Chairman Committee on Chemical Research, and on Steels produced by modern processes.

RAILWAY NOTES.

TRACTION ENGINES ON ROADS.—The Larne traction engine nuisance case has occupied a great deal of time in its hearing, and a very considerable amount of our space. We do not say that either the time or the space was wasted; but we feel sure that even our good friends in the neighborhood of Larne must be gratified that the case has at last been concluded. The magistrates gave their decision yesterday. It was adverse to the plaintiffs, as the court held that a traction engine traversing the public road did not constitute a nuisance. Railways frequently ran close to public roads; and their engines might practically be regarded as forming a nuisance equally with traction engines, supposing these were nuisances; but railways run under Acts of Parliament and could not be prosecuted as nuisances. The magistrates held that traction engines also had the sanction of Parliament, and did not think that in this particular instance a nuisance had been proved. In particular, it was remarked that though the engine was regularly driven through the town of Larne, none of its inhabitants had come forward to complain of it. The charge was, therefore, dismissed; and we think there is substantial justice in the decision. It is no doubt very annoying to owners of horses to have them frightened on the public road; but the evidence on this point was not particularly strong, and without a very strong case indeed, the court would not have been justified in giving a judgment which would have had the effect of prohibiting the use of traction engines altogether.—*Northern Whig, Belfast.*

BOILERS LINED WITH COPPER.—An Austrian railway engineer has had the idea of protecting the boilers of locomotives against incrustation by means of copper plates. The front and back plates of the bottom of the boiler of an engine were covered with a sheet of copper 1 millimetre in thickness, the middle plate of the boiler being left unprotected. The engine was worked for two years on a portion of the line of the State railways where the water was of very bad quality. When the tubes were taken out the incrustation was found to be 10 millimetres in thickness on the surface of the iron, and only 2 to 3 millimetres thick on the copper plates. The iron was in many places corroded to the depth of $1\frac{1}{2}$ millimetres, while the copper was entirely unaffected, and the iron plate beneath it, when uncovered, looked perfectly new. The particles of incrustation were larger on the iron than on the copper. The cost of the copper covering is stated to be from 250 to 750 fr. per boiler. Another engineer, who examined and reported on the arrangement, says that the duration of the boilers is doubled or tripled by the application of the copper plates, which afford extraordinary security against explosion. The incrustation is much less on copper than on iron and steel, which is porous and slightly oxidized, and consequently the vaporization is more complete, and there is a corresponding saving of fuel. In the construction of a boiler to be lined with copper the iron plates may be of less thickness without risk; the weight of the boiler is thus considerably reduced, and, lastly, the expense for repairs is considerably diminished.

[This combination of copper and iron in iron ships has been found very injurious on account of the galvanic action between the two metals, and we would need more satisfactory experiments with water of different qualities, and particularly with the acid water common in coal mines before placing much value on this "improvement."]—*Engineering and Mining Journal.*

STEEL RAILS was the subject of a paper recently read before the Institution of Civil Engineers, London.

The object of this paper was to endeavor, briefly, to show that with care in manipulation and in selection of materials, Bessemer steel might be produced constant in quality, and that certain inexpensive tests might be applied which would absolutely determine the quality of the material, in most if not all of its characters, so far as was required for railway and structural purposes.

After an entensive experience in the manufacture of Bessemer steel rails, the author could only come to the conclusion, that the present system of inspection was highly unsatisfactory, and that, whilst it sacrificed a great number of rails, it gave anything but reliable results. The object appeared to be to test each individual rail in such a manner that its value should not be deteriorated. With this view many experiments had been made; and it was hoped that a system had been developed which, although primarily adopted for rails, might be made available for any other form of steel. The experiments appeared to prove that if it was possible to determine the hardness of the material, all the other properties might be calculated therefrom. If, therefore, the fish-plate holes in the rails were punched by a registering punching press, an index was obtained for the real quality of the steel. Experiments had shown that this force increased according to the thickness of the metal, in strictly arithmetical progression; for a hole $\frac{7}{8}$ in. in diameter the force required was about 8 tons per $\frac{1}{8}$ in.

Experiments had demonstrated that the zone of metal injured, by punching steel having a tensile strength up to 32 tons, did not exceed $\frac{3}{32}$ in. in breadth, and that if the fish-plate holes were first made with a small punch and then enlarged, by drilling to the required size, the steel was not more injured than if the hold had been drilled only. The Barrow Steel Company had shipped to Canada more than 100,000 tons of rails treated in this manner; and as there had been no case, to their knowledge, where rails had broken through

the fish-plate holes, they considered it a satisfactory proof that no danger need be feared. On the contrary, this mode of punching was one of the best practical tests of the quality of the steel; as, however hard (unless in an exceptional degree) it might be, the particular rails, if drilled, might be overlooked by the management; whilst if the steel had a greater tensile strength than 34 tons to 35 tons, the punch would break, when the rail would necessarily be rejected.

The results of experiments on rails, for the Furness Railway, also proved, that the punching strain was a true index of the steel as to its carbon percentage, tensile resistance, ductility, and the force required to give a permanent set. A fresh series of experiments on rails, which had been in use for several years on the same line of railway, proved that, contrary to what might have been anticipated, greater hardness had not conduced to the longevity of the rails, and that the softer ones showed the minimum of wear.

To sum up the experiments on Bessemer steel rails, it might be stated generally, that the most lengthened wear, under the heaviest traffic, did not appear in the slightest degree to deteriorate any portion of the rail, except the wearing surface to an inconsiderable depth. But this part of the rail, however hard and capable of resisting impact, lost almost the whole of its ductility, which was apparently due to the extreme molecular tension of the particles of the metal. If a worn double-headed rail was turned, though the new wearing table would be as strong as when first made, yet the total strength of the rail was materially lessened by the weak under-table, by which much of the elasticity of the rail was destroyed; though, by planing off a thin section, this, as had been demonstrated by experiment, could be entirely restored, allowing for a proportionate decrease in the weight of metal.

ENGINEERING STRUCTURES.

THE SEWAGE OF PARIS.—The question of disposing of the sewage of Paris is constantly being discussed from one point of view or another. The municipal council received a report the other day from M. Desouches on the construction of a proposed sewer to connect the departmental collector of the Rue d'Allemagne with the great receptacle of night soil at La Villette, and thus allow of the sewage of the Pantin sewer, which now falls into the Seine at Saint Dennis, being carried on to the plain of Gennevilliers, where it may be employed in irrigation. M. Desouches recommended that the sewer should be constructed, but that the contents should be conducted to the plain in question only as an experiment, and after being diluted with at least five or six times its volume of the water of the Ourcq. It should be mentioned that the water of the Ourcq, brought to Paris by the canal which runs under the Place de la Bastille, is very impure water, only used for cleansing purposes. A member of the council said that recent discoveries had been made, which promised that the sewage might be purified sufficiently to be turned into the Seine without any inconveniences; but the council, knowing how little had in reality been effected in the way of artificial purification, and how costly all the processes are, passed over that part of the subject, discussed the general subject, and finally adopted the report. This will form an important link in the long chain of the application of the sewage of Paris, as the depot of La Villette is the receptacle of an immense quantity of night soil.—*Engineer.*

THE KANSAS CITY BRIDGE.—An absurd and injurious rumor appeared last week in an Atchison paper to the effect that the piers of the railway bridge at Kansas City are being undermined by the current, and that negotiations are making for a ferry boat for immediate use with which to transport the cars across the river. This would, indeed, be a misfortune, if true, for some forty trains cross the bridge daily, and it would be impossible to provide for their passage in any other way than by the construction of a new bridge.—There is, however, a certain basis, or occasion, for a rumor, exaggerated and false as it is. It has been "an open secret" that the pivot pier is partially undermined (on the north side, we believe) a fact known almost from the erection of the bridge, but not to an extent immediately impairing its stability. However it was deemed best to apply the ounce of preventive which is better than the pound of cure; and so, in December last, a thorough examination of the defective foundation was made by a submarine diver. It was found that a small portion, not exceeding one-twentieth of the whole, is defective, though there is no evidence that the break in the masonry has increased for some time. The examination was made by Mr. O. B. Gunn, who suggested a plan for repair, under which a contract was made in February last with the American Bridge Company of this city, which is now prosecuting it under the supervision of Major Gunn. The plan is that of a caisson to be built at the site of the pier and sunk around it; the intervening space being then relieved of water, the masonry will be restored beneath the pier, which will then be surrounded by a solid wall of masonry and caisson work, 11 feet thick, making it as secure and permanent as any pier on the Missouri River. When the contract was made, in February, as Major Gunn explains, it was too late to take advantage of the ice, and the unprecedented flood of April which has so delayed work upon the Atchison bridge, has prevented the repairs being made before this time. All the machinery, tools, timber, stone, etc., required are, however, delivered, and the caissons are framed, ready to be built and sunk around the pier as soon as the water is at a favorable stage, by the same men who have sunk the piers of the Atchison bridge, quicker and more successfully than any work of the same magnitude ever heretofore done in this country.—*Railway Review.*

ORDNANCE AND NAVAL.

THE twentieth iron steamship launched from the yard of John Roach & Son since October, 1871, went into the water at Chester, Penn., on Saturday, 5th June. Her name is the "City of New York," and she was built for the Pacific Mail Steamship Company, being the second of their last order of three vessels now in different stages of completion. Each of these three ships is 353 feet long, by 40½ feet wide, with a depth of 39½ feet from the hurricane deck and 31 feet from the spar deck. They will each be of a capacity of 3,500 tons, custom-house measurement, with accommodations for 153 first cabin and 1,200 steerage passengers.—*Bulletin.*

THE trial trip of the Solimoes, a monitor recently launched by the Compagnie des Forges et Chantiers de la Mediterranée, was made a few weeks since. This vessel, which is built for the Brazilian Government, is a specimen of the latest improvements in naval architecture, gunnery, and engineering. The deck is only 90 cent. above water line, and hence has the appearance of a large raft 78 metres in length by 18 beam, with a draught of about 11ft. The cabins and engine-room are naturally below water line. She is propelled by a beautifully finished pair of engines of 550 nominal horse-power, but indicating 2000 horse-power. This vessel carries four Whitworth's guns weighing 25 tons each, mounted two to each turret. The weight of the projectiles is 275 kils., requiring a charge of 35 kils. of powder. These guns have given excellent results, and at a trial of their range carried a shot of 275 to a distance of 11 kils. (nearly 7 miles).

THE Alexandra will be propelled by vertical compound twin-screw engines, which are to indicate not less than 8,000 horse-power. There are three cylinders to each set of engines, two low pressure cylinders of 90 in. diameter being placed on either side of the high-pressure cylinder, which is 70 in. in diameter, with a stroke of 4 ft. The surface condensers will have more than 14,000 solid drawn brass tubes, 7 ft 4 in. in length, and ⅝ of an inch outside diameter; the water for the condenser will be driven by means of centrifugal pumps worked by separate engines. To ensure perfect command when handling, separate starting engines are provided. To give proper ventilation for the stokeholes, ventilating engines and fans are fitted. Steam will be supplied by twelve boilers, placed in two stokeholes forward of the engines. The boilers are proved to 120 lb. to the square inch, but will be worked only to about 60 lb. The brass stern tubes, in connection with the screw propellers, are the largest and longest in the English navy. Each is cast in one piece, is 34 ft. in length, and weighs several tons.

MERCHANT NAVIES.—The *Magdeburg Gazette* publishes statistics showing that, although the German navy consists at present of only twenty-three vessels, with sixteen gunboats and six torpedo boats, the Mercantile Marine ranks next to those of England, America and France. It consists of 219 steamers of 165,178 tons, and 263 sailing ships of 1,143,810 tons. The former have increased since 1867 by nearly 50 and the latter by more than 20 per cent. It has nearly reached the strength of France, which has 316 steamers of 240,275 tons and 4951 sailing vessels of 906,705 tons, its tonnage having thus already exceeded that of the French Marine. England and its colonies have 4343 steamers of 1,641,000 tons and 32,461 sailing ships of 5,573,000 tons, while America has 3,625 steamers of 1,048,205 tons and 17,049 sailing ships of 2,146,585 tons. Next to Germany comes Russia with 185 steamers of 36,000 tons and 3089 sailing vessels of 771,292 tons. Austria has ninety-seven steamers of 52,005 tons and 2692 sailing vessels of 288,176 tons. Sweden has 406 steamers of 22,000 tons; Italy, 118 steamers of 37,810 tons, and as many as 19,488 sailing vessels of 1,031,907 tons; and Spain, 151 steamers, mostly colonial, of 45,514 tons and 4363 sailing ships of 345,186 tons. The merchant navy of Germany is manned by 90,000 sailors, while that of France has 96,000.—*Iron.*

THE Vienna paper *Naval News* gives some information as to the present state of the Austro-Hungarian navy. The iron-clad fleet consists of four casemate ships, the Custozza, Lissa, Erzherzog Albrecht, and Kaiser, each with from fourteen to sixteen guns, engines from 800 to 1000 horse-power, and a tonnage of from 6000 to 7000. There are also 7 iron-clad frigates. The first-class, comprising the Erzherzog Ferdinand Max and the Hapsburg, have sixteen guns, engines of 800 horse power, and a tonnage of 5200; the second, consisting of the Kaiser Max, the Don Juan d'Austria, and the Prinz Eugen, are being converted into casemate ships; and the third, the Salamander and Drache, have fourteen guns, engines of 500 horse-power, and a tonnage of 3120. The unarmored fleet consists of three frigates, eight corvettes, five gunboats, one torpedo ship five schooners, two aviso steamers, two yachts, two Danube monitors, one factory ship, and ten training ships. The above shows that the number of ironclads has remained unchanged since 1872; of the unarmored ships, one gunboat and two steamers have been placed on the non-effectrve list, and two corvettes and two schooners have been added. The establishment of officers now consists of 1 admiral, 2 vice-admirals, 5 rear-admirals, 52 captains, 117 lieutenants, 145 ensigns, and 87 cadets. The number of seamen was increased in 1874 from 5702 to 5836, 3557 of whom on the average serve on board ship. The health of the navy is, on the whole satisfactory, and great progress has been made in the organization of the naval schools.

BOOK NOTICES.

SYSTEMS OF PROJECTILES AND RIFLING, WITH PRACTICAL SUGGESTIONS FOR THEIR IMPROVEMENT, AS EMBRACED IN A REPORT TO THE CHIEF OF ORDNANCE. By Capt. JOHN G. BUTLER, Ordnance Corps, United States Army. New York: D. Van Nostrand. Price $7.50.

For some years past Capt. John G. Butler, of the United States Ordnance Corps, has given unremitting attention to the improvement of projectiles, and rifled cannon, and he has now embodied the result of his investigation and experience, with the consent of the Chief of Ordnance, in a handsome volume, which will be of great utility to his brother officers, and of very general interest. In dealing with the question he arranges the different forms of rifling and projectiles under three general systems—the expansive, embracing all projectiles which in loading are inserted in the gun without respeect to the rifling, but which "take the grooves" by the action of the gases of discharge upon a device or feature of the projectile which is readily expanded thereby into the grooves of the gun; the compressive, embracing all projectiles which are loaded in a chamber, and then forced by the action of the powder through the bore of the gun, the diameter of which across the lands is less than the superior diameter of the projectile (all projectiles for breech-loading guns have heretofore been of this class); and the flanged system embracing all projectiles upon the cylindrical portions of which are projections which in loading are intended to be inserted into corresponding grooves in the bore of the gun. These projections may be studs or buttons, ribs or flanges, grooved shot being nothing more than flanged shot with wide flanges.

The simplicity of the expanding system, says Capt. Butler, strongly recommends it for muzzle-loading guns, and especially for field calibres, where rapid firing is a desideratum. Its advantages, indeed, are numerous and well acknowledged, but the defects of different projectiles of this class have been so many and serious as to more than counter-balance in the opinion of many the admitted advantages of the system. He proposes then a system of rifling and projectiles which removes these objections and defects. The rotating device consists of a double-lipped annular band or sabot attached to the base of the projectile. A narrow camelure between the upper and lower lips of the sabots distributes the gases of discharge so evenly that the slightest irregularity in the expansion of the upper lip has never been discovered; at the same time ballotting is almost entirely prevented. It is officially recorded that in the course of upwards of 100 rounds with the proposed projectile suoh a thing as a fluttering or in the slightest degree unsteady flight was never discovered. The upper lip of the grooved ring may be made so thin as to almost entirely check windage, and yet possess sufficient strength to rotate the heaviest shot. It may also be made so extremely thin as to close windage while the projectile is getting under way, but through sheer lack of stiffness ride over the lands towards the muzzle. The behavior of the new projectile is all that need be desired; it gives very superior accuracy, great steadiness and smoothness of flight, there was not a single case of stripping, though over 100 projectiles were fired, and not a single failure to take the grooves.

With regard to projectiles of large calibre and maximum weight, Capt. Butler does not deny that they might be benefited by a more substantial centreing, and he gives the diagram of a double centred shot, but it is found that his system is sufficiently accurate for all practical purposes. In discussing the compressive system he follows the same course, first points out and comments upon the principal defects, and then explains the methods of removing them. He adopts the same principle—the double-lipped annular sabot—as with muzzle loaders, and explains that there can be no undue strain from the checking of windage. The sabot is forced no more deeply into the grooves than occurs in a muzzle loading gun, while the slight quantity of gas which escapes is distributed evenly about the projectile. He mentions that if it be thought desirable in the use of either of the expansive projectiles described to entirely close the windage, this can be done very readily by a soft lead ring in front, or by a thin flange on the base of the projectile; and on the other hand, if windage is desired in the chamber as well as in the bore it can easily be effected by grooving the sabot by attaching it in segments, by grooving the chamber longitudinally with channels too narrow to admit of the sabot being forced into them, or by three or more holes running diagonally through the base of the projectile, and terminating at its cylindrical portion, but he considers the system better as it is.

Of course the practical value of a system can only be determined by actual experience, but it cannot be questioned that that advocated by Capt. John Butler is scientifically correct, since it secures accuracy of aim, perfect rotation with the least possible fatigue to the gun, owing to the reduction of friction to the minimum, absence of ballotting, and, probably also from the rotation being secured with so little friction between the gun and the projectile uniform and high velocitites. The projectile is so thoroughly strong that slight carelessness in manufacture or inferiority of materials do not seriously affect its value, whilst it can be roughly handled both in storing and transportation, is comparatively inexpensive, and does not injure the gun. Capt. Butler's book should be read by every officer of ordnance, to whatever country he may belong.—*London Mining Journal.*

SCIENCE SERIES. SKEW ARCHES: ADVANTAGES AND DISADVANTAGES OF DIFFERENT METHODS OF CONSTRUCTION. By E. W. HYDE, C.E. New York: Van Nostrand. Price 50 cts.

The combination of strength, elegance, and economy in the designing and construction of a skew arch of more than limited span is a fair test of the ability of an engineer; and although when brick is the material used there is really little choice in the matter, it is probable that a more intimate acquaintance with the principles involved would lead to the adoption of stone in many cases where it is now neglected. To facilitate the acquisition of the requisite knowledge, the excellent little treatise of Mr. E. W. Hyde will be found very useful, since it contains the result of the author's careful personal investigation, chiefly with a view to ascertain the relative security and the

relative facility of construction, and descriptions of the manner of making the necessary draughts, templets, &c. To facilitate the systematic consideration of the subject he treats of the helicoidal, the logarithmic, and the corne de vache, or cow's horn methods separately, explaining that the first two named are derived from the nature of the coursing and heading joint surfaces and their intersections with the soffit, and the third from the soffit itself, which is a warped surface that has been thus named.

Commencing with the helicoidal method, he explains the mode of draughting the arch, and then investigates the security of an arch, constructed according to this method, remarking that in order that there may be no tendency in the successive courses to slide upon each other it is evident that the coursing joint surface must be at every point normal to the direction of the pressure at that point. It is probable that the direction of pressure varies somewhat with reference to the vertical plane in different portions of the arch, especially if the crown settles to any extent after removal of the centre. Still it must be approximately parallel to the plane to the face, otherwise portions would be left unsupported and fall. He assumes that it must be parallel, and then explains the nature of the curves, and the direction of their tangents at the point of piercing the soffit, subsequently giving an analytical investigation of the curves.

Similar information is then given with regard to the logarithmic, and the Corne de Vache methods, and the author then discusses the relative advantages of each. There is one advantage, he remarks, possessed by the helicoidal method over each of the others—it may be constructed of brick. This is owing to the fact that the successive coursing joint curves are parallel, so that the voussoirs, except those at the end of the courses, are all exactly alike, while in the other methods each stone is different from the next one, though the two halves of the arch on each side of the keystone are alike, so that any stone cut for one side will fit also in the corresponding place in the other side. The fact that the different voussoirs are alike in the helicoidal method of course lessons the labor of preparing the drawings, and of making the necessary measurements. As regards the difficulty of cutting the stones, this method does not seem to have any serious advantage over the others even when the approximate method is adopted, while if the coursing and heading joint faces were cut with exactness as helicoids the difficulty would be fully equal if not greater than that by the other methods. It may be considered an advantage as regards appearance that the quoin stones should be all alike, or rather those faces of the quoin stones which coincide with the faces of the arch. This, of course, is the case only with the helicoidal method. He thinks, however, that the gradual decrease in the size of these faces from one side of the arch to the other would not be displeasing to the eye when taken in connection with the direction of the coursing joint curves, which would make the reason for the decrease obvious.

The real test, however, of the relative value of the different methods would appear to be that of security. When this test is applied the logarithmic and cow's horns methods both exceed by far the helicoidal. In the last-mentioned when semi-circular there is always a tendency to sliding on the coursing joints both above and below a certain point; that is, the assumed direction of pressure is nowhere normal to the coursing joint except at a certain height above the spring plane equal to $r \sin. 39° 32' 23''$, and that near the springing plane this tendency to sliding increases rapidly with the obliquity up to $a = 20°$ (about); while in the logarithmic method along each coursing joint curve this tendency is zero—that is, the assumed direction of pressure is normal to the coursing joint surface in any of the coursing joint curves, and in the cow's horn the tendency is small as compared with the helicoidal. The logarithmic method, therefore, seems to approximate to theoretical perfection as regards security, is followed closely by the cow's horn, and at a great distance by the helicoidal. The cow's horn soffit admit of plane coursing joints, which are not feasible in the others, and thus possesses an advantage over them, if such an approximate construction be desirable. If cheapness be an important item to be considered, the last-mentioned method would seem to present most advantages, as avoiding almost entirely the use of curved surfaces, and at the same time reducing the sliding tendency to a small amount. If the main thing to be considered is security the logarithmic method must stand first.

From the manner in which Mr. Hyde has handled the subject, the reader will have no excuse for failing to comprehend it thoroughly, and whether he desires merely to understand the scientific bearing of the question, or to make the necessary drawings, patterns, &c., to apply his knowledge practically the volume, which is amply illustrated, will give him all the information he requires.—*London Mining Journal.*

MISCELLANEOUS.

THE STEAM MAGNET.—M. Donato Tommasi states that, if a current of steam at a pressure of 5 to 6 atmospheres is passed through a copper tube of 0.08 to 0.12 inch in diameter, and coiled spirally around an iron cylinder, the latter is magnetized so effectually that an iron needle, placed at the distance of some inch or two from the steam magnet, is strongly attracted, and remains magnetic as long as the steam is allowed to pass through the copper tube.

ARTIFICIAL HARDENING OF SANDSTONE.—Manfred Lewin has tried with success in his quarries at Saxonia, and at Neundorf, near Pirna, a process of impregnating sandstone. The stone there quarried is porous and readily absorbs water to a certain depth; it is this fact which renders it possible to introduce a solution to harden the surface. Lewin impregnates the stone with solutions of an alkaline silicate and of alumina; there is thus

formed an aluminum silicate within its pores, which gives to the surface considerable resistance. The solutions employed are made with soluble glass and with aluminum sulphate. After the impregnation, the sandstone may be polished like marble, which it then resembles closely. Heated to a high temperature, the exterior layer vitrifies and thus may be colored at pleasure. The coloration may even be obtained simply by mixing the desired pigment with one of the two solutions used for the impregnation.

CLEOPATRA'S NEEDLE.—The fine obelisk which goes by this name was offered to the British Government in 1820, by Mahomed Ali Pasha, but has never been removed owing to the difficulty of transit and also a report that it was much defaced towards the base. A short time since General Alexander wrote to say that he had gone to Alexandria for the purpose of examining the prostrate obelisk and had found it, with its hieroglyphic inscription in perfect preservation. On the authority of experts he asserts that its safe transport to England is quite practicable, and proposes that it should be erected on the Thames Embankment. General Alexander, on the same authority, states the cost at £10,000, for which he suggests a Parliamentary grant, observing that this is just an eighth part of the sum expended by the French Government in the transport and erection of the obelisk of the Place de la Concorde. There cannot be two opinions regarding the ornamental effect of this fine relic on the Embankment—a work itself in extent and strength worthy of ancient Egypt; and in the present state of engineering art there should be no difficulty in bringing it over and placing it.

WHITE BRASS BEARINGS.—In the case of bearings for shafts and axles the value of the metal alloy used can only be ascertained by actual practical experience, a circumstance which prevents many inventors of really useful alloys from even getting their material tested; it would seem, however that at the present time this causes but little inconvenience, since the economy and durability of white brass really leaves nothing to be desired. Although somewhat similar in color, white brass, or as it is more commonly called Parsons' white brass, differs essentially from what is generally called white metals, and should not be classed with them, being harder, stronger, and sonorous; it is, in fact, as its name implies, a species of brass, and behaves like it under the tool when bored or turned, it does not clog the file, and is susceptible of a very high polish; at the same time, it fuses at a lower temperature than ordinary brass, and can be melted in an iron pot or ladle over an ordinary fire, which renders it exceedingly useful for fitting up engines and machines where first cost is an object, as it can be run into the plummer-blocks or framing to form the bearings, bushes, sockets, &c., without the expense of fitting or boring them, or it can be cast in metal moulds, or, like ordinary brass or gun metal, in sand or loam. It has now been in use for many years for railway carriage and engine bearings, shafting, rolling-mills, fans, and the wearing parts of many other kind of engines and machines.

Except when used as carriage-axle bearings it is difficult to obtain a reliable comparative test of the durability of bearing metal, owing to the impracticability of having the bearings in competition with each other, working simultaneously, and under precisely corresponding conditions; fortunately, however, the wear of a carriage axle bearing so accurately represents the varying speeds, pressure, &c., met with in one or other class of industrial machinery that an alloy which can successfully pass through the ordeal of continued use under a railway carriage is accepted with every confidence as applicable wherever bearings are employed. The manner in which Parsons' White Brass passed through this ordeal is most satisfactory. Two white brass bearings were put under one end of a Great Northern brake van, and at the same time two ordinary brass bearings were put under the other end, and the van was run 19,200 miles, or twenty-four trips to Edinburgh and back, and it was found that whilst the White Brass had diminished in weight but 2 ozs., the ordinary brass had lost no less than 2 lbs. 4 ozs. Under two third-class passenger carriages(same railway and conditions) the white brass lost 2¼ ozs., against 1 lb. 6 ozs. and 1 lb 12 ozs. respectively of ordinary brass during 20,000 miles running; the locomotive engineer remarking that the bearings ran perfectly cool, and were lubricated with oil. The break-van bearing, after it had run the 19,200 miles and weighed, was replaced, and the following week the van was again put in a train, this time running 24,956 miles, or 31 trips to Edinburgh and back.

As the van then required varnishing it was in the shop at Doncaster for a month, when it was brought into use again, and up to the saturday preceding the date of the report it had done another 20,556 miles, making 64,712 miles in all, the locomotive engineer then writing—"These bearings are yet in very good order, and but little worn."

With such results as these it is not surprising that the manufacturers assert that the white Brass has been found, by carefully conducted experiments, to greatly surpass in durability all other kinds of anti-friction metal against which it has been tested, to reduce friction to a minimum, and effectually prevent heating of the journals. It is equally effective with quick as as with slow speeds, and will work satisfactory under the heaviest weights. Some recent applications also show that it can be used with success to replace worn out bearings even when the journals have been greatly worn and scored from long continued use, without the necessity of returning them. The price of the white Brass being less than that of gun metal or ordinary brass, and its durability very considerably greater, a double saving is effected by its use—first, in prime cost, and secondly, in renewals and repairs, to which, in the case of railway carriages, heavy shafts, &c., which have to be lifted to replace the bearings, should be added the saving in the cost of labor, and the loss arising from stoppages.—*London Mining Journal.*